

R&D Report and FY20 Proposal eRD6 Tracking and PID Consortium

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(For the eRD6 Consortium)



January - June 2019 eRD6 R&D Report

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 - Brookhaven National Lab (BNL)
 - Florida Institute of Technology (FIT)
 - INFN Trieste (INFN)
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 - Temple University (TU)
 - University of Virginia (UVa)
 - Yale University (YU)
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 - TPC (BNL, SBU)
 - Cylindrical μ RWELL (FIT, TU, UVa)
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Report on Central Tacking

Report on Central Tracking

Overview: Central Tracking

❑ BNL, Yale

- Study of MPGD readout structures and FE electronics for a TPC.

❑ SBU

- Investigate IBF blocking structures to be used in MPGD based readout structures for a TPC.

❑ FIT, Temple, UVa

- Investigating use of μ RWELL operating in μ TPC mode as a possible alternative technology in a second IR, and/or in addition to TPC or silicon detector.
- Simulation of cylindrical μ RWELL operating in μ TPC mode.
- Design of small cylindrical μ RWELL prototype.

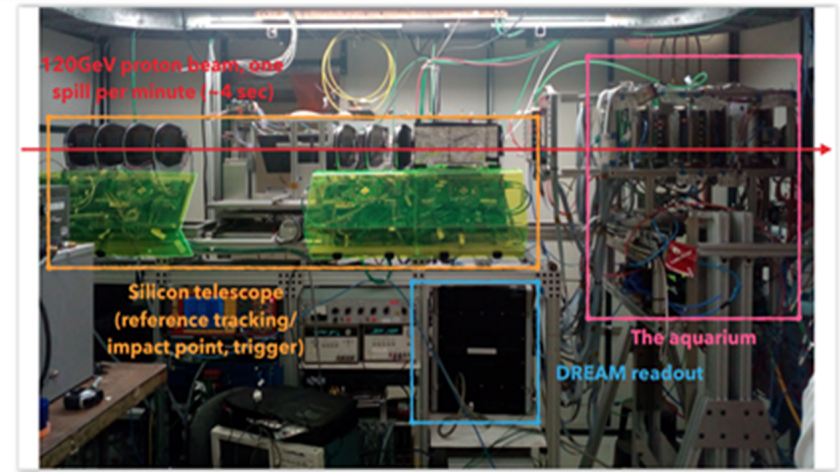
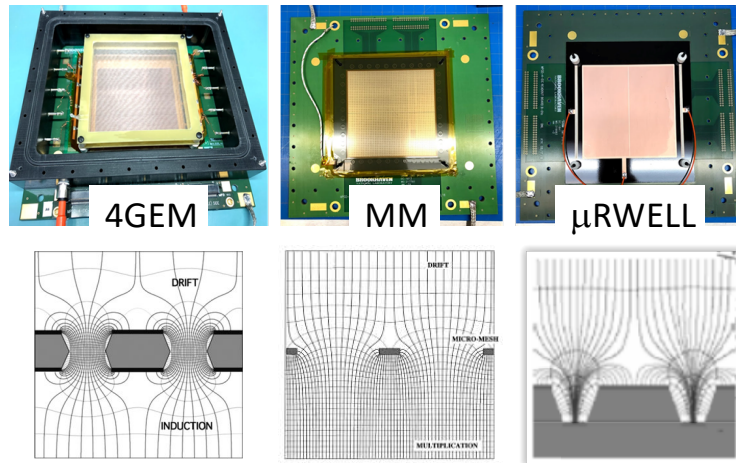
❑ UVa

- Procurement of SRS-VMM readout system.

Beam Test at Fermilab

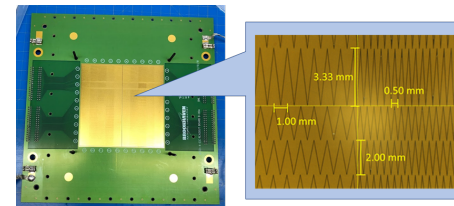
❑ Evaluation of MPGD-based readout possibilities for TPC, tested in a planar detector configuration with “multi-zigzag” PCB

- 4-GEM
- Micromegas (MM)
- μ RWELL
- 2GEM+MM hybrid

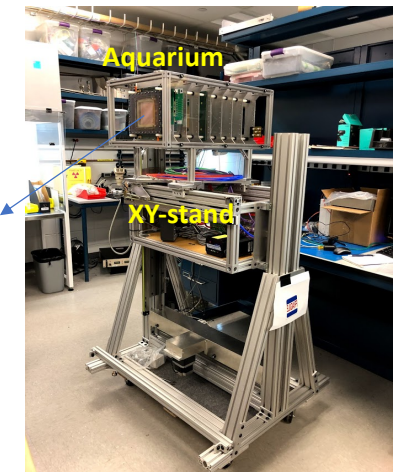


❑ Apparatus

- “Aquarium” (fixture that holds 8 detector layers back to back)
- XY-stand (precisely translates aquarium in beam)
- **DREAM** front end electronics (suitable FEE for TPC: 4096 ch. read out @ ~ 10 kHz; 20 MHz ADC; $>10 \mu$ sec memory depth)
- Silicon reference tracker ($\sim 20 \mu$ m resolution for extrap. tracks)



“Multi-zigzag” PCB with array of 100 ZZ patterns on a single board



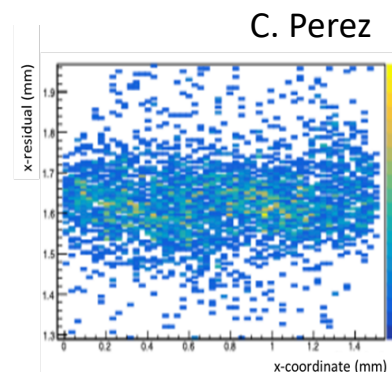
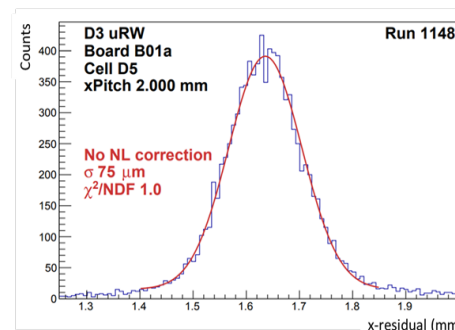
Preliminary Beam Test Results

Method

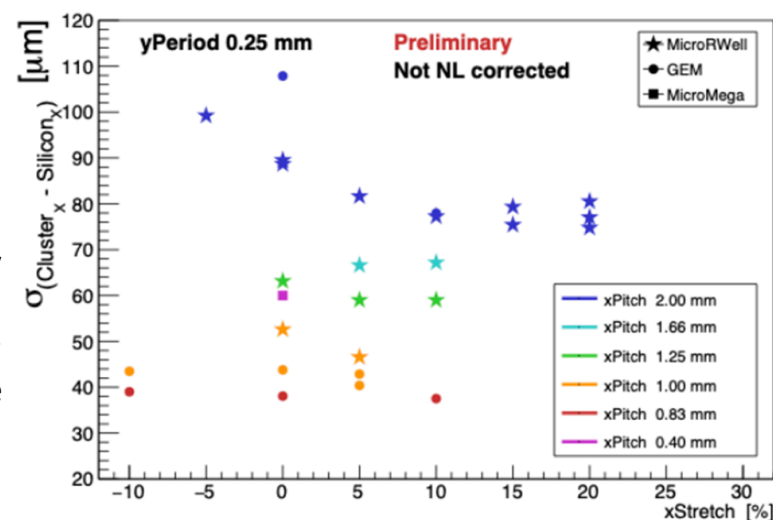
- Initially, the coordinate system of each detector layer is aligned with the Si coord. Sys.
- A centroid (or charge weighted mean) is calculated for the distribution of charge collected at the readout plane for each event trigger.
- A position residual is formed with the silicon data.
- The residual distribution is fit to a Gaussian and the width (sigma) reveals the resolution.
- In this case, no corrections are made for any differential non-linearity (DNL) and in some cases the x-residual vs. the x-coord. scatter is flat, with no DNL, which is a highly desirable result.

Results

- The goal was to compare the position resolution from the different avalanche schemes across many zigzag pattern options
- For the GEM and μ RWELL, the resolution approaches 40 μ m, but only for a pitch of ~ 1 mm.
- So far it appears that the trends in resolution are more or less similar for the different avalanche technologies, which is surprising since the charge develops very differently in each case.
- However, the analysis is incomplete and there is not yet enough data to make absolute conclusions .



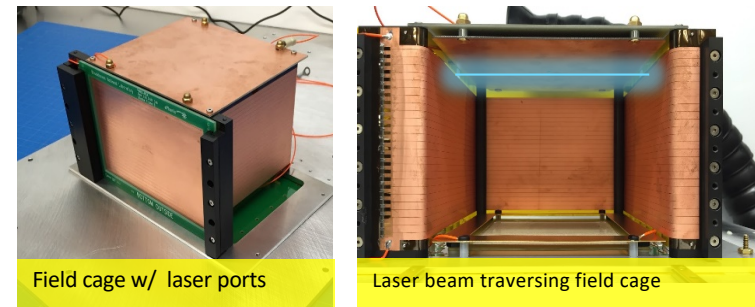
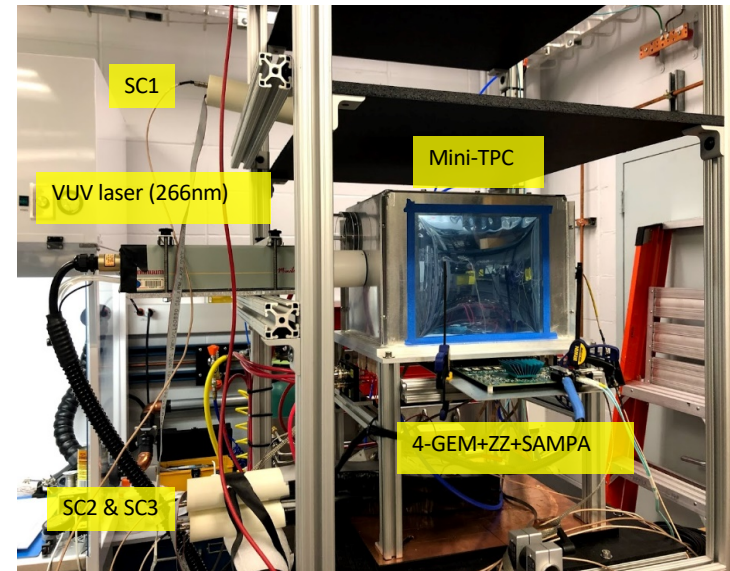
C. Perez



Measurements with TPC Prototype

❑ Setup

- 10cm x 10cm x 10cm field cage coupled to 4GEM w/ 2mm pitch ZZ readout.
- The TPC was studied with the **SAMPA** readout (TPC: 512 ch.; 20MHz ADC; >10 μ sec memory depth)
- Initially shot a laser beam into the field cage to create a line of ionization to mimic particle tracks.
 - Faster and more convenient than triggering on cosmics.
 - Will start work on developing a laser-based system to generate lines of charge in gas volume for benchtop tests (can also vary angle!).
- Also set up a cosmic trigger using the coincident signal from three scintillation counters (SC1-3).

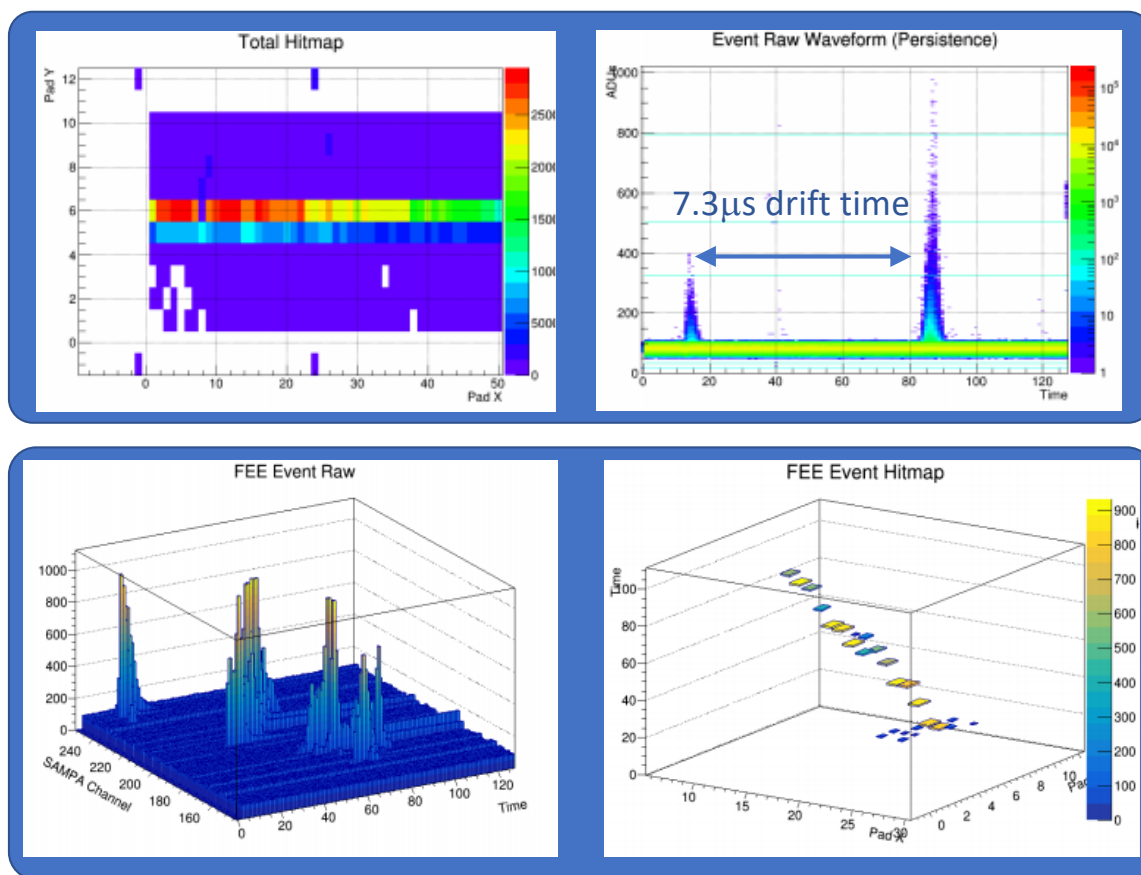


Initial Results with TPC Prototype

J. Kuczewski

Results with laser track

- Hit map on left shows clear line of charge collected by the **SAMPA** FEE along a pad row.
- The peak in red is due to the use of lens to focus to beam, but ionization is still detected after the beam defocusses.
- The right plot shows a drift velocity measurement made possible by triggering on the laser with a photodiode.
- The measured value corresponds well to the expected value, thus validating the timing capabilities of the SAMPA.



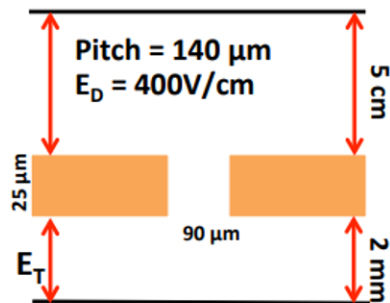
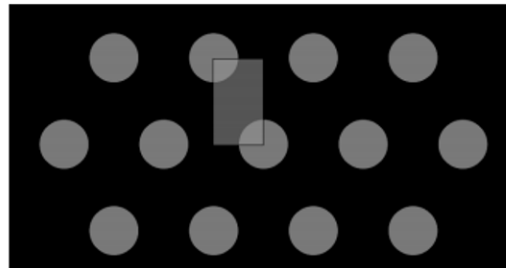
Results with cosmics

- The left plot shows digitized waveforms of the **SAMPA** FEE, triggered by the cosmic trigger.
- The right plot shows an example of reconstructed points along a cosmic track in 3D.

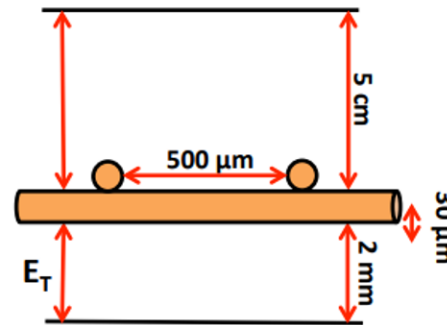
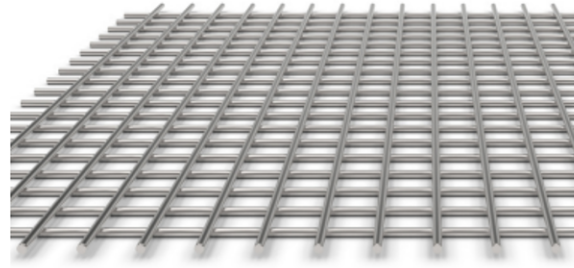
TPC Studies at SBU

- ❑ Investigation of IBF blocking structures to be used in an MPGD based readout structure for a TPC.
- ❑ Concept of a passive gating grid.

Cylindrical Holes Gating

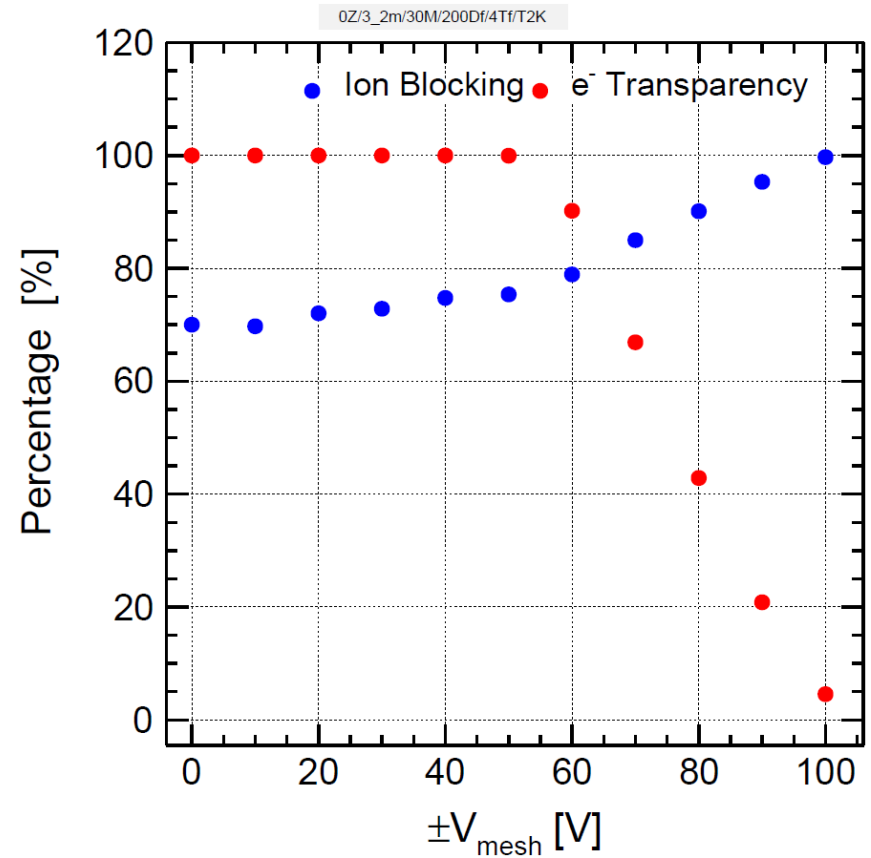
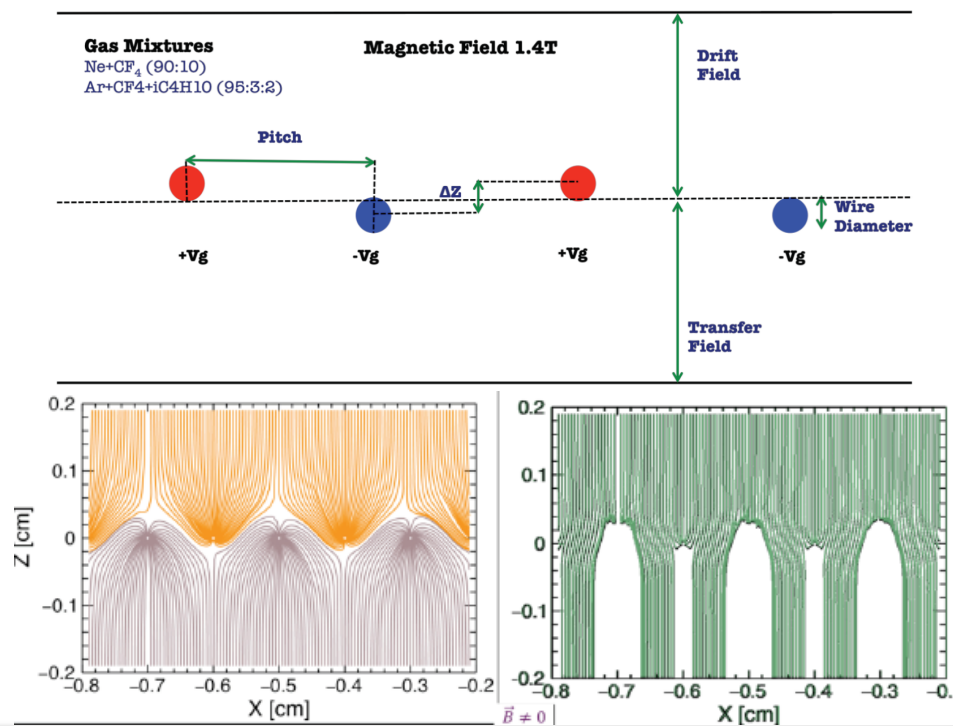


Wire Mesh Gating



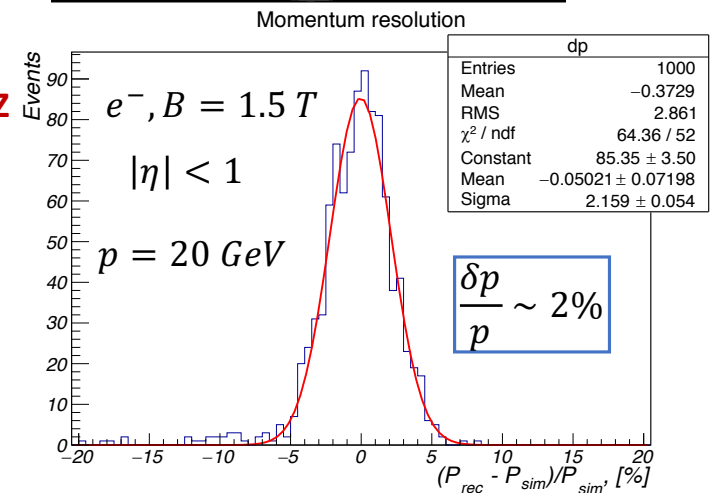
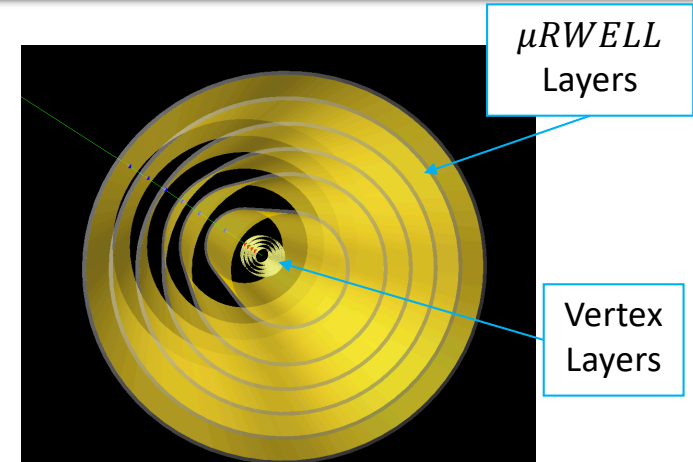
TPC Studies at SBU

- ❑ Investigation of IBF blocking structures to be used in an MPGD based readout structure for a TPC.
- ❑ Concept of a bipolar passive gating grid.



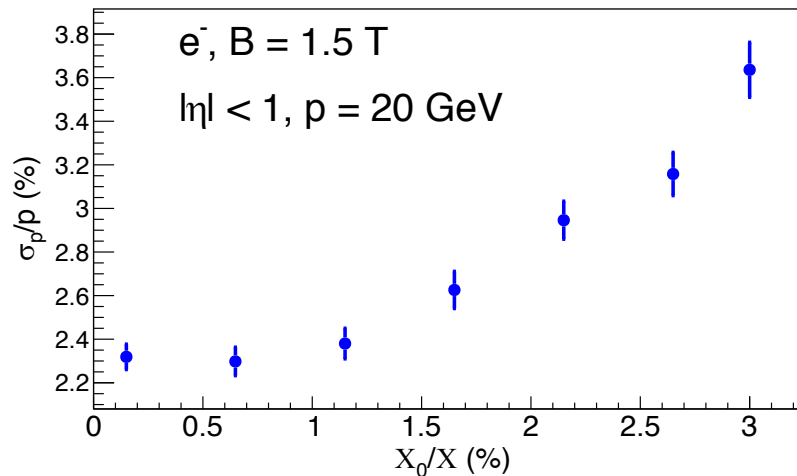
Cylindrical μ RWELL Simulation: Momentum Resolution

- ❑ Initial simulation Investigates central tracking system consisting of silicon vertex detector and cylindrical μ RWELL operating in μ TPC mode within EicRoot.
 - μ TPC mode will allow reconstruction of Z track and could reduce material budget from more traditional central tracking solutions.
- ❑ **Silicon vertex detector**
 - Four silicon layers each with **X-Y** pixel resolution of **20 μ m – 20 μ m**
- ❑ **Cylindrical μ RWELL Barrel Tracker**
 - Detector material implemented based on low-mass μ RWELL model, $\frac{x_0}{x} = 0.17\%$.
 - Additional **15 mm of ArCO₂** is implemented as the drift gap.
 - Each of the **6 cylindrical layers** is assigned a resolution of **100 μ m** in the **Z** and **transverse** directions.
 - Cylindrical layers are **2 m** long (in Z-direction) and cover radii from **225-775 mm**.
- ❑ Initial momentum resolution looks promising.
- ❑ Simulation needs to be made **more realistic** by implementing dependence on track angle, number of hit points per layer, dE/dX resolutions ...
 - A μ RWELL μ TPC prototype would be beneficial



Cylindrical μ RWELL: Momentum Resolution

- ❑ The current simulation is based on an **optimistic low-mass** μ RWELL detector, the current material budget is **larger ~ 1 -2%**.
- ❑ Using current EicRoot simulation framework/setup (previous slide) a study of **momentum resolution vs. material** was done.
 - Performed by **TU undergraduate summer student**, Seamus Gallagher.



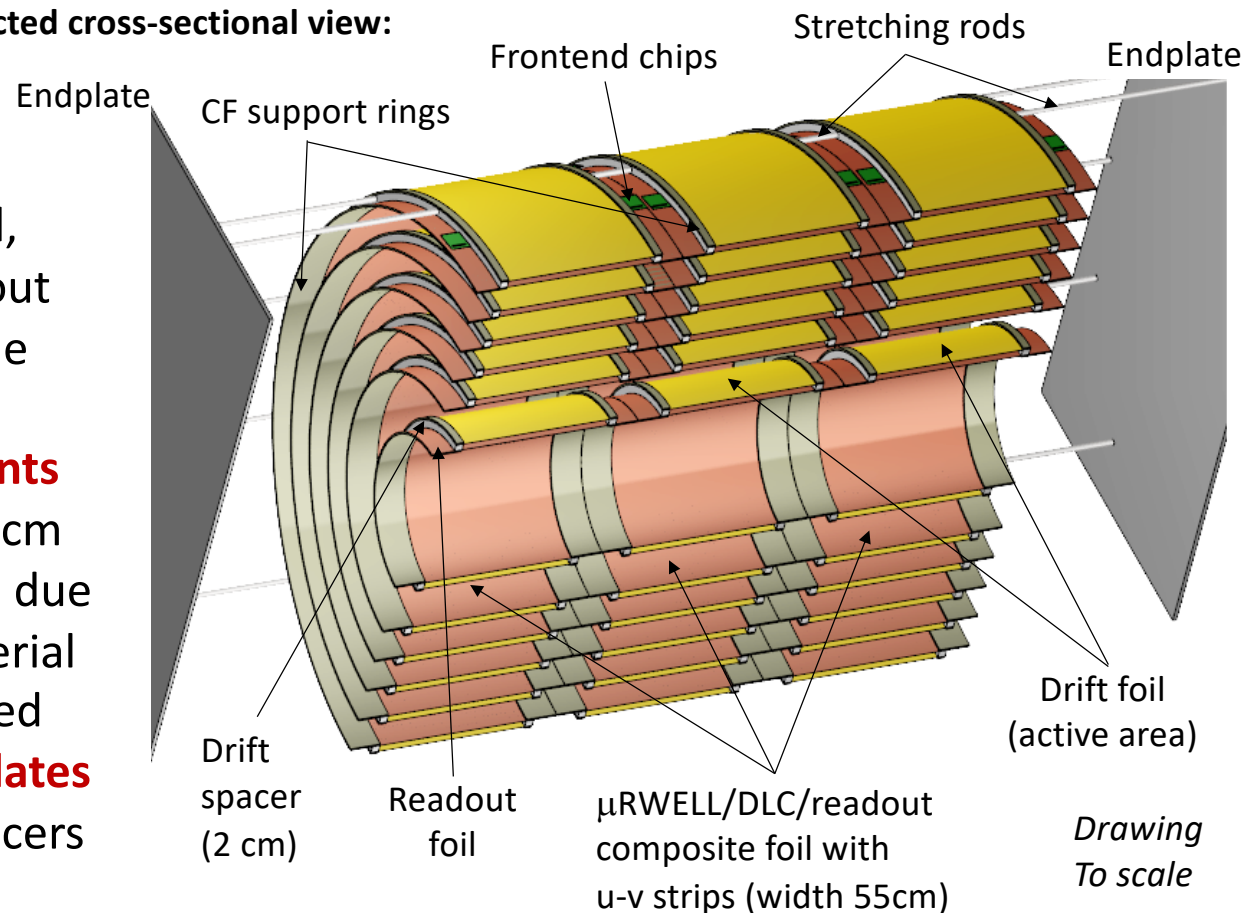
- ❑ To study **track residuals**, it is **critical** that we implement a convenient way to **access the reconstructed tracking information** within the EicRoot framework.

Conceptual Design Studies - Cylindrical μ RWELL for EIC Barrel Tracker

Projected cross-sectional view:

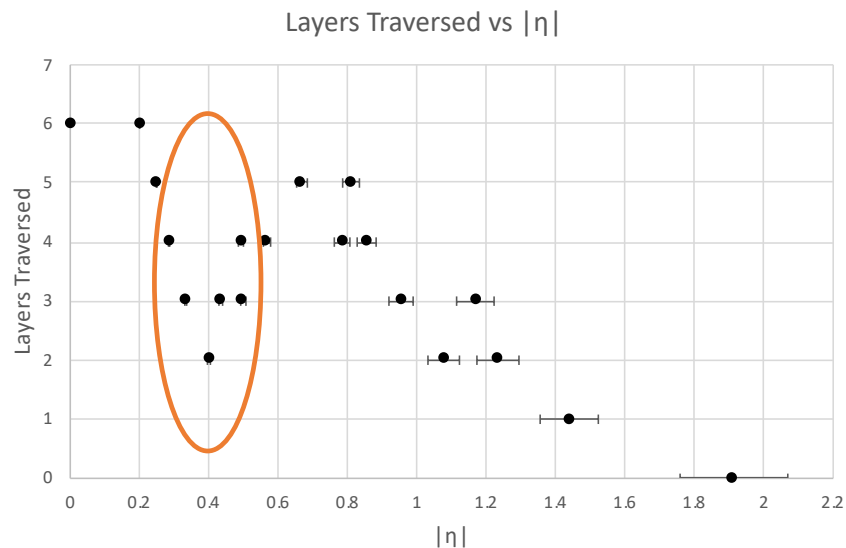
❑ Latest Design:

- **Foil-based design** with drift foil, composite μ RWELL /DLC/readout foil, and drift spacer forming the active gas volume
- Three connected **barrel segments**
- Geometry is constrained by 55 cm maximum width of readout foil due to given width of foil base material
- Foils in each layer to be mounted by and **stretched against endplates** using rods attached to drift spacers

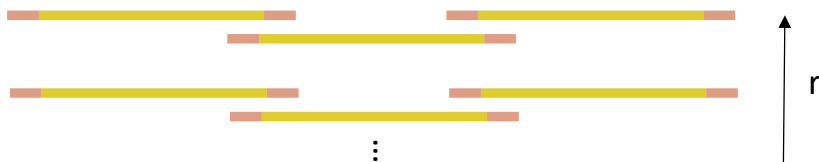


Next Steps - Cylindrical μ RWELL for EIC Barrel Tracker

□ Estimate of Pseudorapidity Coverage :

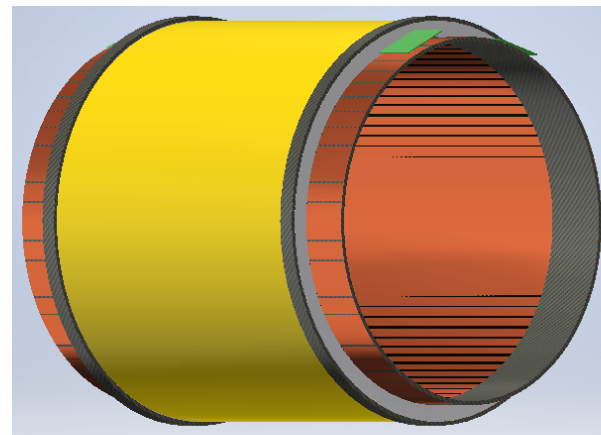


- Dip around $|\eta|=0.4$ is due to gap between segments
- => Next design will stagger layers and overlap segments:



□ Plan for next R&D period:

- Continue CAD work on the full barrel tracker
- Build a **mechanical mock-up** for a single cylinder
 - Motivation: Check if foils that have their ends spliced together will give proper cylindrical shape when stretched in the proposed manner
 - Build smallest “mock cylinder” with three segments
 - Use inexpensive parts:
 - Basic kapton foils
 - 3D-printed frames



Characterization of the UVa 2D-strips μ RWELL prototype

❑ μ RWELL prototype tested extensively with cosmic

- Cosmic setup include two GEMs for precise efficiency measurement .
- All chambers operates with Ar-CO₂ (70/30) – APV25 SRS for the readout .

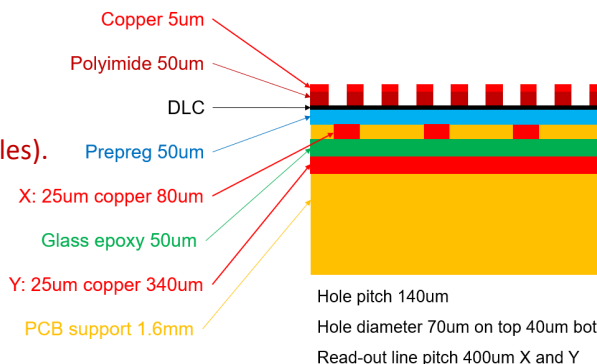
❑ Efficiency, gain and drift electric field

- HV scan of μ RWELL: Efficiency and gain (600V = 120 kV/cm in μ RWELL holes).
- Scan of the drift electric field: **No effect on the detector performances.**

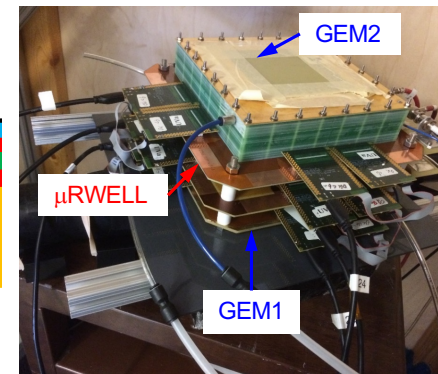
❑ Performances of the 2D-strips readout

- Good X-Y charge sharing correlation @ a X/Y charge ratio = 0.8
- Cluster size (average number of hits / event) > 2.5 for 580 V on μ RWELL .

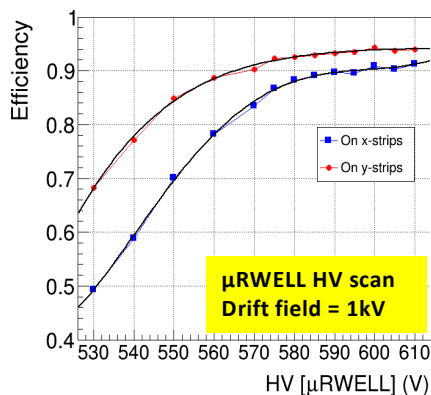
Cross section of UVa μ RWELL prototype



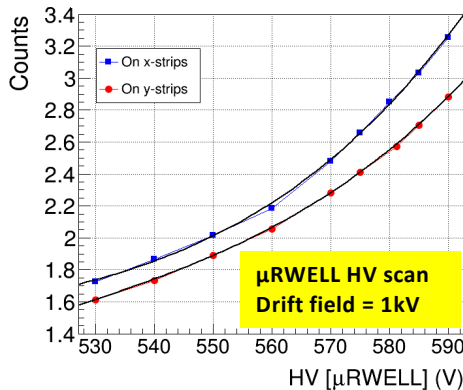
μ RWELL on cosmic setup @ UVa



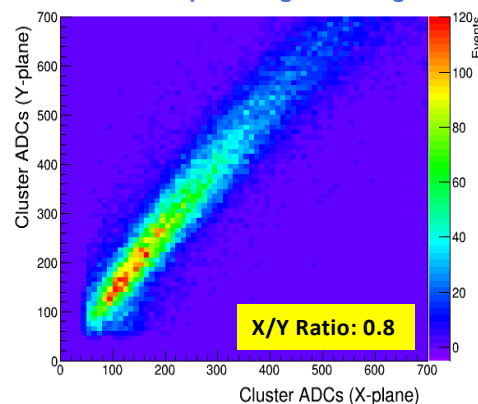
Efficiency vs. amplification



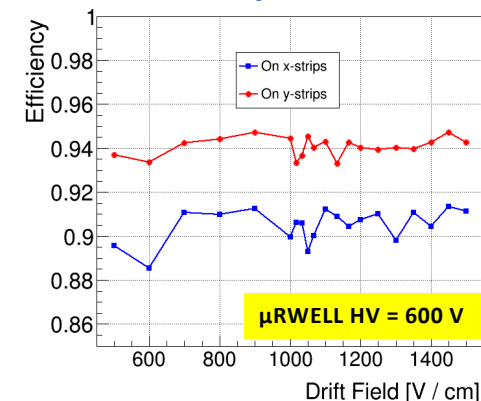
Cluster size vs. amplification



X-Y strips charge sharing



Efficiency vs. drift field



Timing performances of the prototype

❑ Gain uniformity: 2D spatial distribution of the average charge (ADC channels)

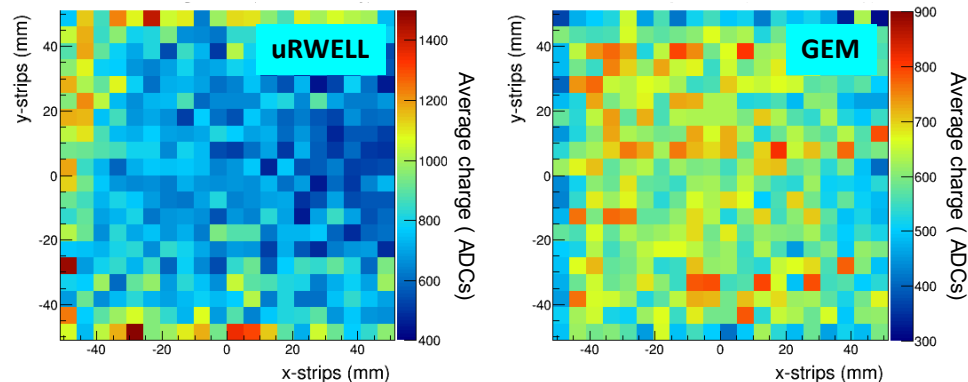
- Non uniform spatial gain (**up to factor 3 variation**) as compared to GEM.
- Non uniform distribution of μ RWELL holes or non homogeneity of DLC layer.

❑ Timing performance: Distribution of APV25 signal peak time w.r.t to trigger

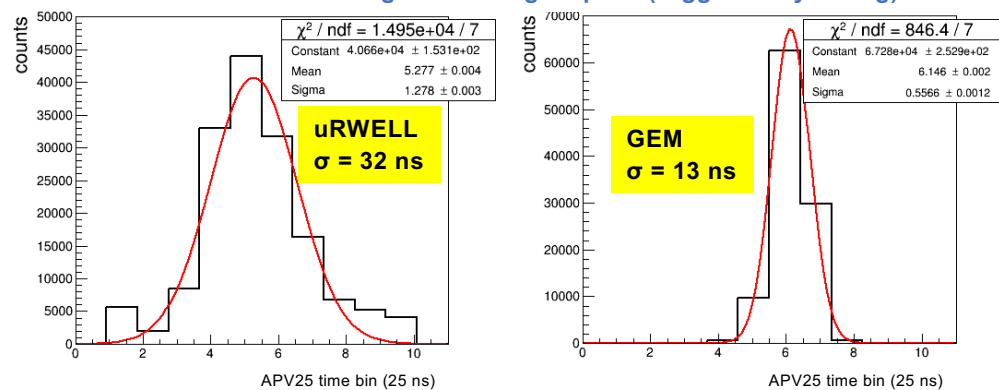
- Signal peak in APV25 time bin #6 for the GEM and time bin #5 for μ RWELL.
- Width of the distribution (spread over bins #5 and #7) for GEM is due to APV25 jitter.
- **Wider distribution with a width of 32 ns for μ RWELL \Rightarrow non homogeneity of structure.**
- 2D spatial distribution of the APV25 peak time confirm the non uniformity of μ RWELL time response (as compared to GEM) .

- Good correlation between gain and time non uniformity.

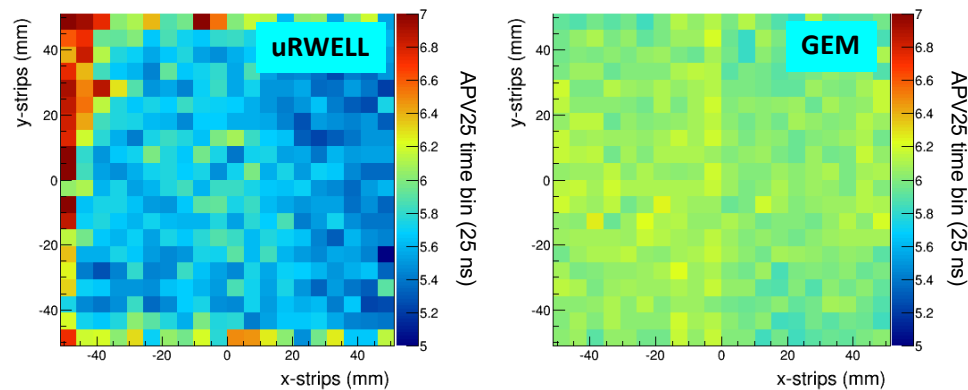
Spatial distribution of average ADCs (gain uniformity)



Distribution of average APV25 signal peak (trigger delay timing)



Spatial distr. of average APV25 signal peak (trigger delay timing)



μ RWELL Prototype @ FNAL Test Beam (June - July 2018)

❑ The prototype was tested at the FNAL test beam in July 2018.

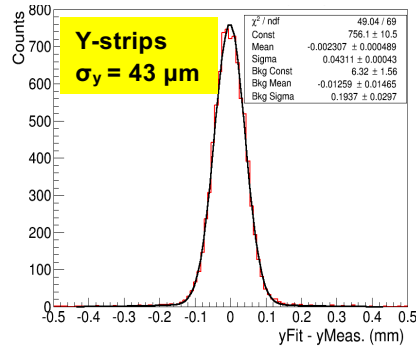
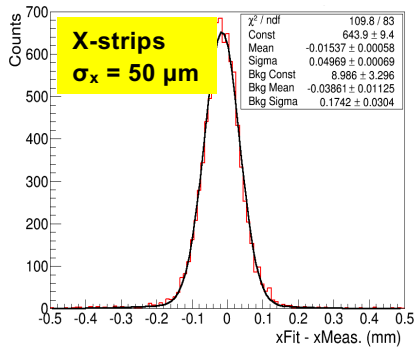
- Operated with standard Ar-CO₂ (70/30) .
- 4 BNL GEMs in the setup for tracking .
- Width of track fit residuals: 50 μ m in x and 43 μ m in y.
- Expect even better resolution after track fit correction.

❑ Uniform position resolution across the detector active area.

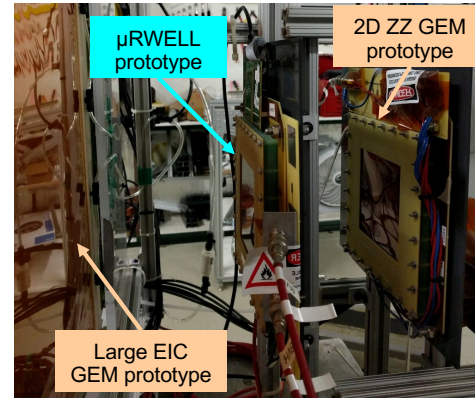
- Position scan with 120 GeV proton beam.
- Good uniformity of residuals width (~63 μ m for x-strips and 53 μ m for y-strips).
- Width of the residual before detector alignment and track fit error correction.

- we anticipate 45 and 40 μ m in x and y respectively.

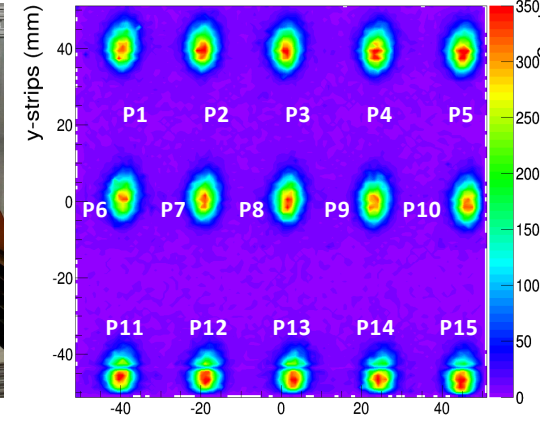
uRWELL position residuals from track fit with GEMs @FNAL



Small Prototypes setup @ FNAL



Position Scan with Proton



Width (σ) of the residuals on various location on uRWELL x and y strips

beam spot positions	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P5
residuals on x-strips in (μ m)	63	62	63	66	66	60	66	69	61	60	60	62	67	66	63
residuals on y-strips in (μ m)	52	53	53	50	53	53	53	49	51	59	58	53	52	53	53

Width of the residual distribution before fine detector alignment and track fit error correction

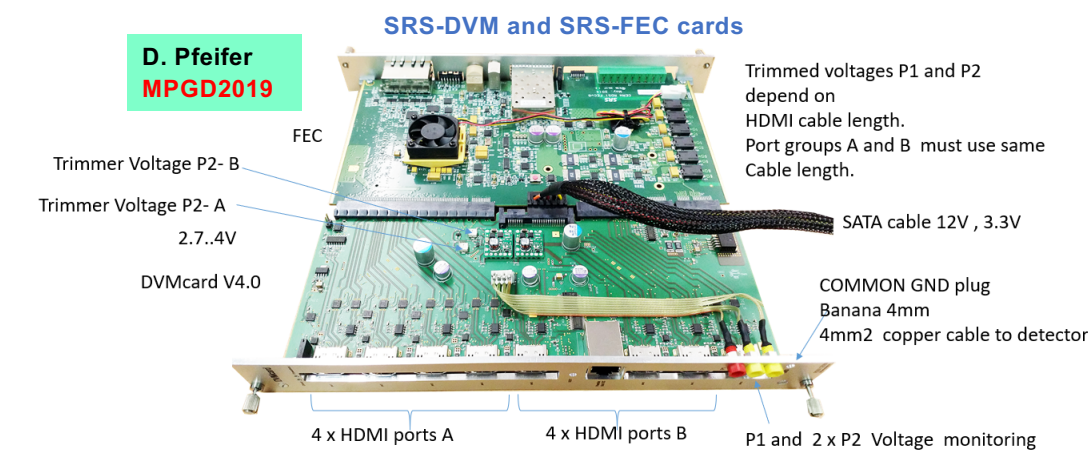
Spatial resolution of uRWELL expected to be significantly better after all corrections applied

- ⇒ we anticipate 45 and 40 μ m in x and y respectively

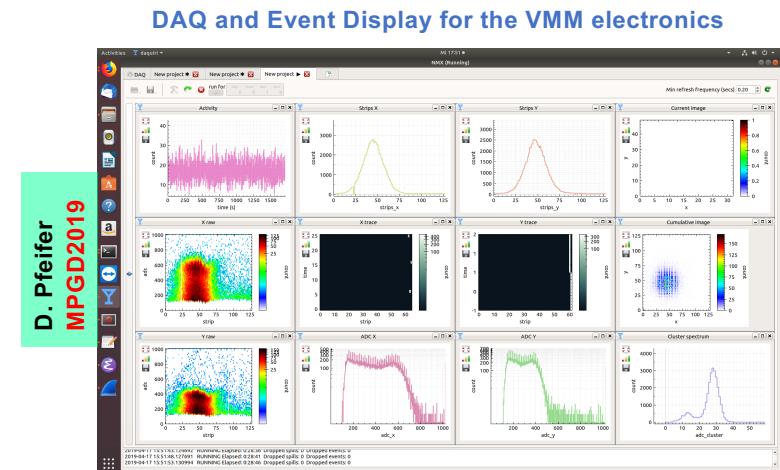
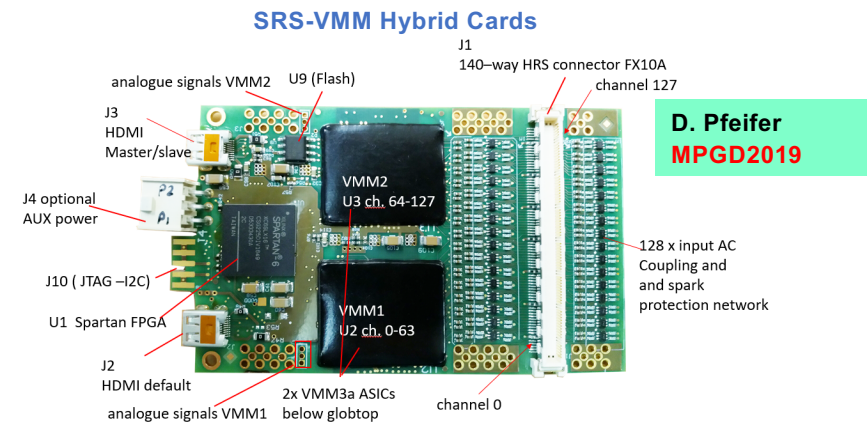
Next: SRS-VMM readout electronics for GEMs and μ RWELL

❑ Procurement of a small scale SRS-VMM Readout Electronics

- VMM chips developed at BNL for ATLAS Muon Detector Upgrade.
- SRS-VMM system developed by the RD51 coll. as a replacement of the SRS-APV25.
- Good candidate for both GEM and μ RWELL for tracking.
- **Should be ideal for μ RWELL operated in μ TPC mode.**
- Complete the acquisition of the small scale SRS-VMM system.
- Familiarize with the system (DAQ & Software installation and configuration etc ...).



https://indico.cern.ch/event/757322/contributions/3425783/attachments/1842281/3021108/2_20190510_SRS_for_VMM_era_HW_Doro.pdf



Report on Forward Tracking

Report on Forward Tracking

Overview: Forward Tracking

❑ FIT and UVa

- Assembly of two low-mass large area ($\sim 50\text{ cm} \times 100\text{ cm}$) triple-GEM detector prototypes.
 - Each uses a different assembly procedures and readout schemes.
 - Used common EIC GEM foils designed by FIT, UVa, and TU.

❑ FIT

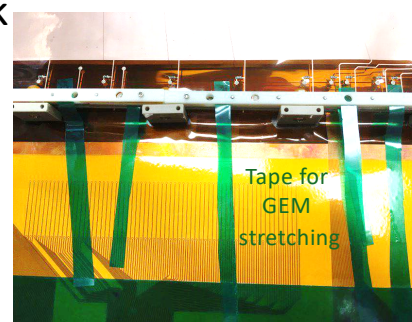
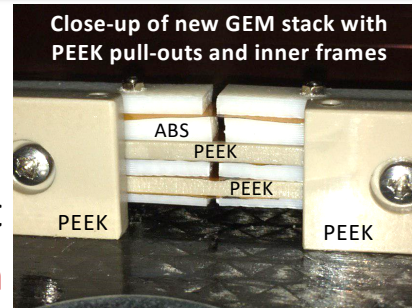
- Simulation of far forward GEM detectors to improve momentum resolution and RICH performance.

❑ TU

- Assembly of 4 low-mass large area ($\sim 35\text{ cm} \times 35\text{ cm}$) triple-GEM prototype.
- Investigate the use of Kapton spacer rings.

Refurbishment of Large Low-mass Forward Tracker GEM with CF frames

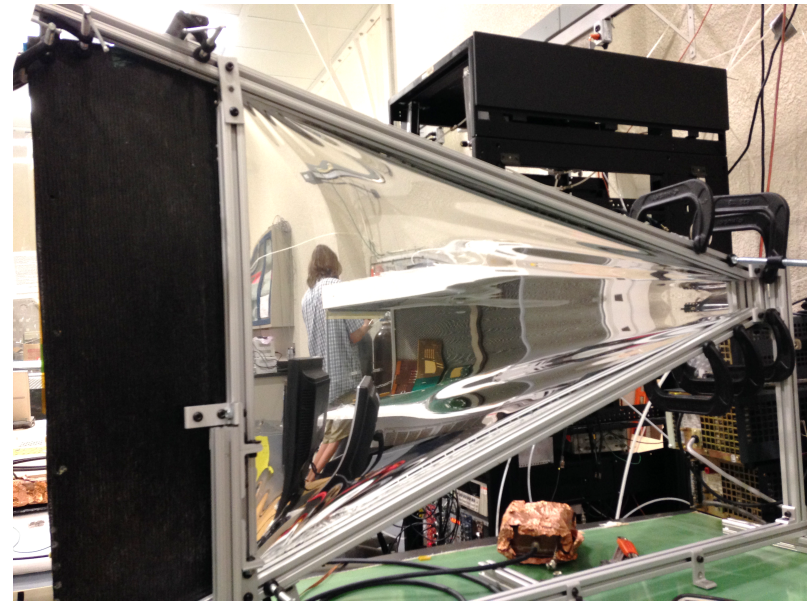
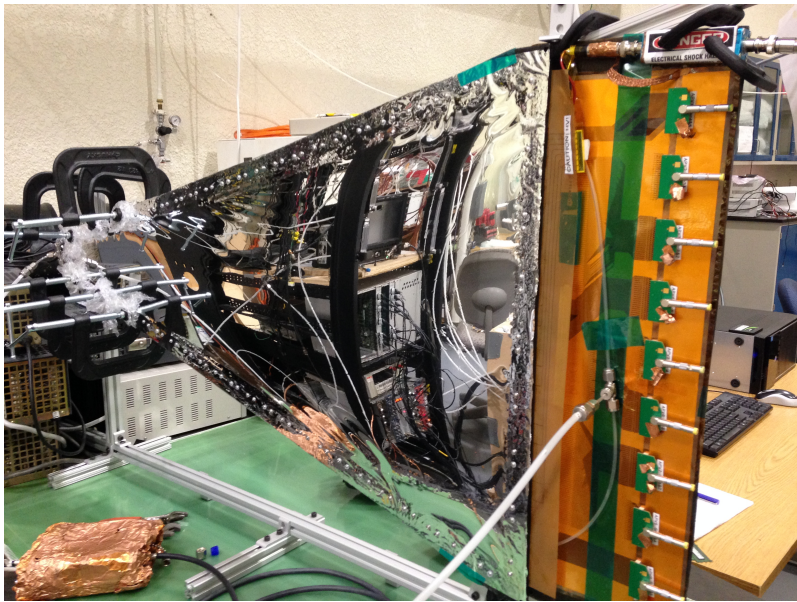
- Large Triple-GEM **without any PCBs** and with Drift and Readout implemented on foils
- Purely mechanical construction (CMS inspired)
- **Carbon fiber (CF) frames** main structural element
- **Had observed short in first transfer gap between G1 and G2 foils** in original 3/1/2/1 mm GEM stack design due to insufficient foil tensioning
- Fixing short:
 - Replaced two layers of 1 mm thick inner ABS frames with **2 mm thick PEEK frames**
 - Replaced original ABS pull-outs with **PEEK pull-outs** to allow more stretching
 - Rebuilt the stack from scratch & pre-stretched each foil with tape during re-assembly
- **Capacitances** of GEM foils and across gaps measured after assembly to check for shorts
 - Observe close to expected capacitance values
 - **No more short** in horizontally mounted GEM stack



Foil / Gap	Cap Avg [nF]
Drift	0.427 ± 0.005
G1	41.002 ± 0.410
T1	0.688 ± 0.009
G2	41.370 ± 0.414
T2	0.549 ± 0.007
G3	41.452 ± 0.415
Induction	0.760 ± 0.010



Refurbishment of Large Low-mass Forward Tracker GEM with CF frames



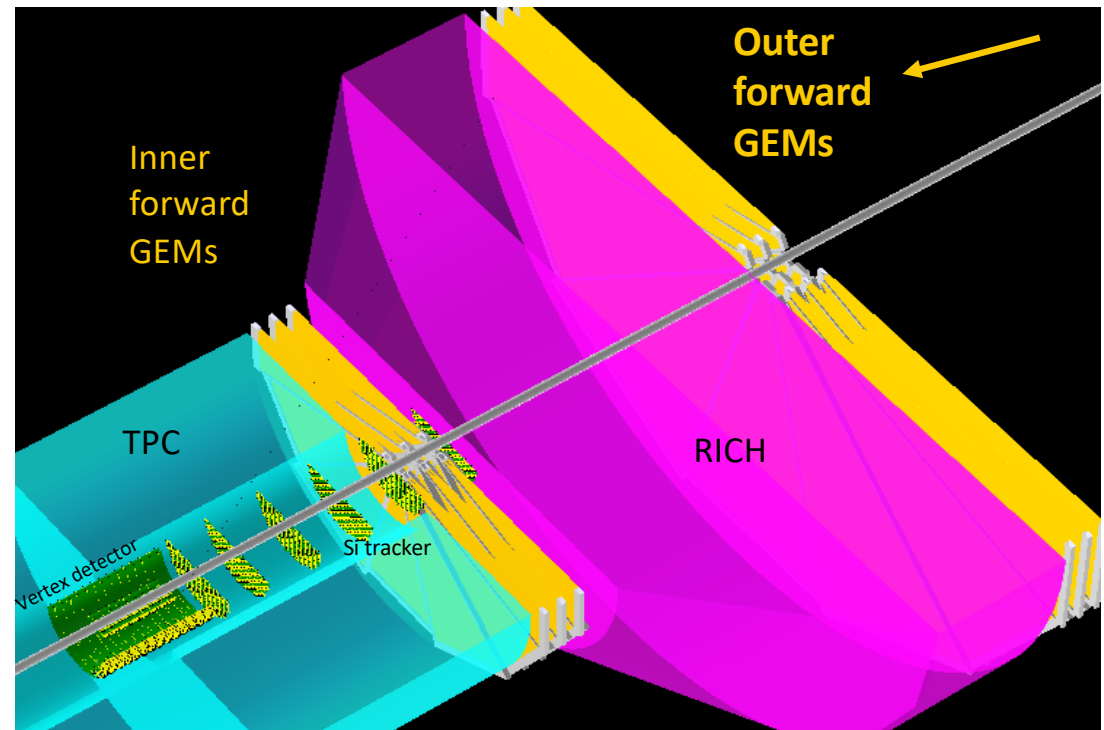
- Short returned when releasing detector from mounts on optical table; this time in induction gap
- Clamping detector onto 80/20 Al bars (see above) removed shorts
- Could ramp HV up to 3650V in pure CO₂, but discharges occurred at higher voltages
- Need to ramp to 4200V for operation, so will need to refurbish some more
- **Conclusion so far:** Current carbon fiber frames not stiff enough to support stretched GEM stack

Simulation: Adding Outer Forward GEMs behind RICH

- We previously suggested to add outer forward GEM detectors to the BeAST design to improve the precision in measuring **track impact points on the RICH**, which will help seeding the RICH ring reconstruction
- Still struggling with extracting track point precisions and track residuals from EICRoot, but...
- ... in the meantime, investigated the impact of outer forward GEM detectors on the **track momentum resolution**

EIC BeAST Detector simulated using the EicRoot framework ($B = 1.5$ T)

Detectors simulated: Vertex tracker, Silicon trackers, GEMs, TPC, and RICH volume

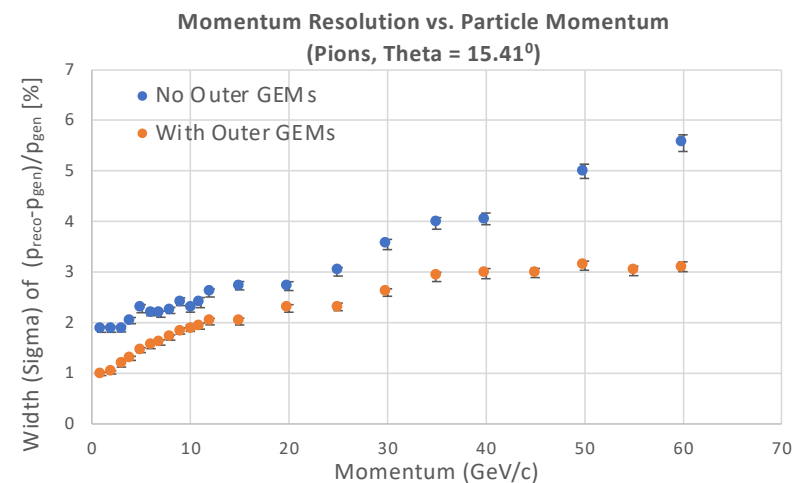
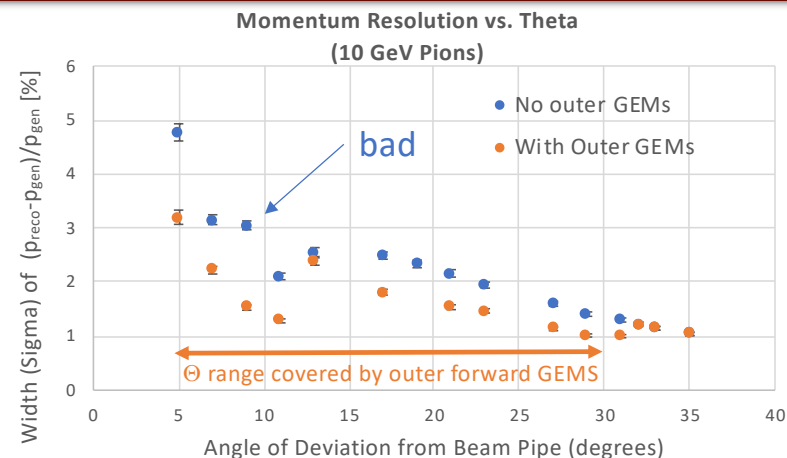
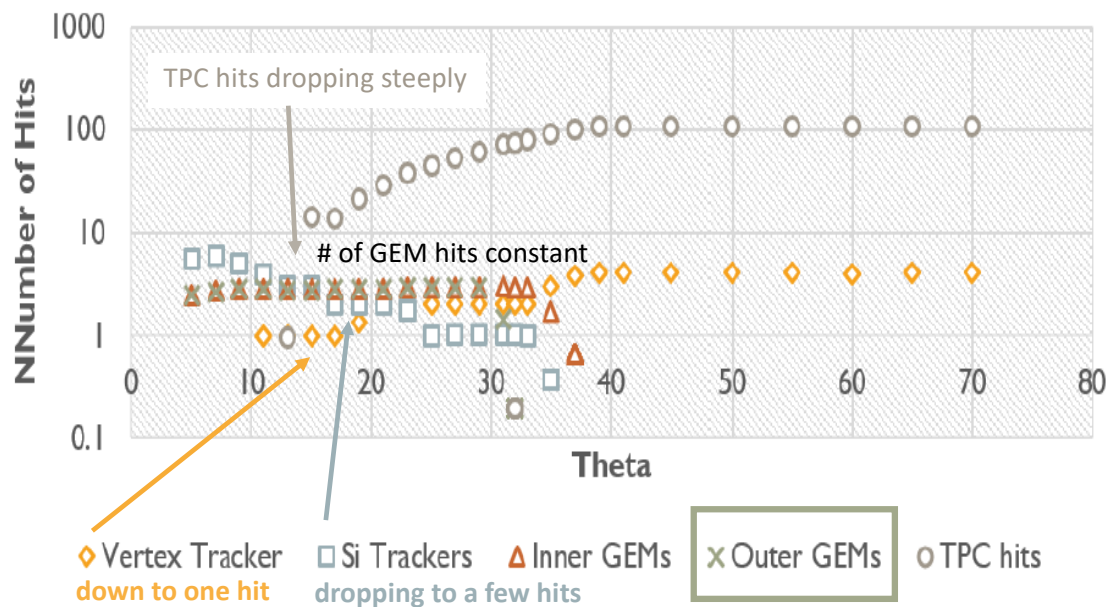


Simulation: Impact of Adding Outer Forward GEMs behind RICH

Impact of adding large area GEMs ("Outer GEMs") to the forward region of the BeAST detector:

- Significant improvement to momentum resolution for tracks that hit the Outer GEMs
- Largest improvements at small angles (< 11 degrees) and for high-momentum particles

Variation of the Number of Hits with Theta

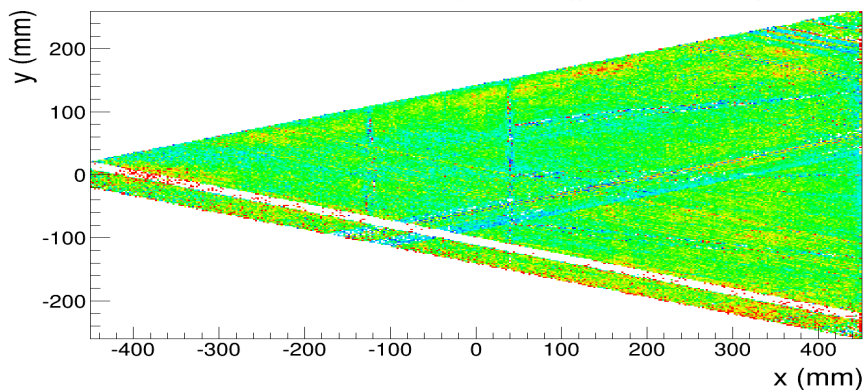


Large GEM prototype With 2D U-V strip readout

3 new ideas developed for the prototype

- Low Mass Detector \Rightarrow radiation length = 0.41%
 - GEMs, cathode & U-V r/o are all Kapton foils
- Low Cost Support Frames \Rightarrow Save \sim 30% in overall production cost (\$)
 - Inner frames for GEMs with spacers, local production for outer frames
- U-V readout with double-sided zebra connection:
 - No electronics on the back or side of the detector

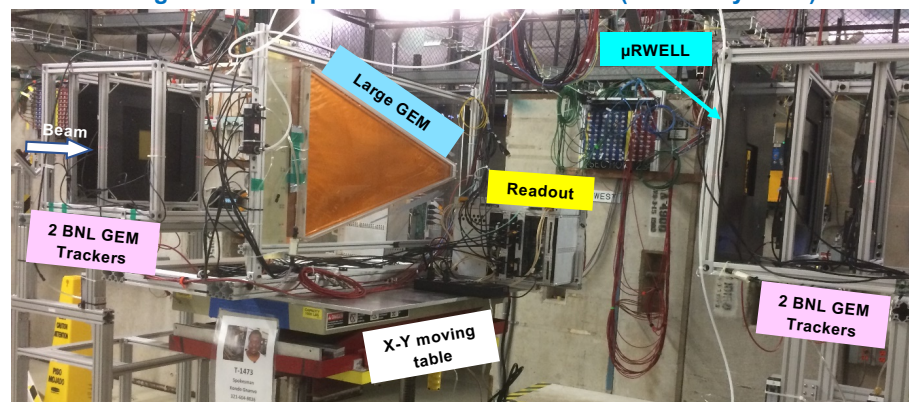
Spatial distr. of average ADCs (gain uniformity)



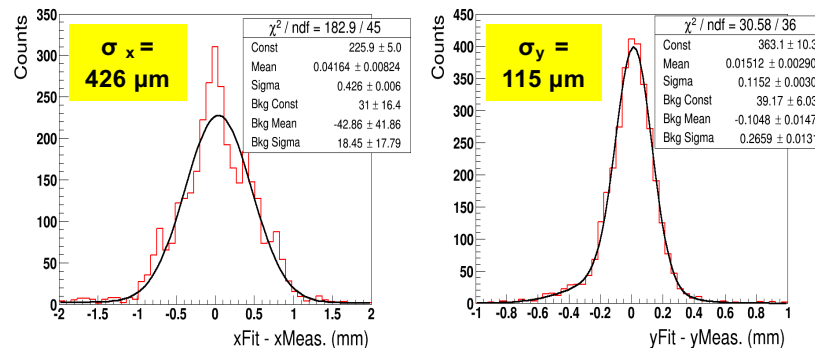
Issues with the test beam data

- Distortion of the reconstructed data: hit position information damaged
 - Discussion with experts \Rightarrow Poor electrical contact or quality of the zebra strips
 - Spatial resolution is degraded more severely where the distortions are strong

Large GEM Setup in MT6.2b Area at FTBF (June-July 2018)



Spatial resolution with U-V strip readout (FNAL data)



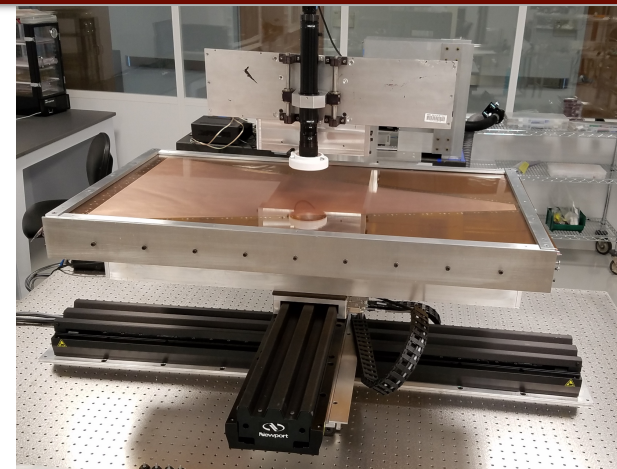
Excellent resolution achieved in both x and y direction with proton beam data \Rightarrow close to EIC Forward Tracking requirements

Plans for FY2020

- Study impact of different zebra strips on the performances of the prototype

Commercial GEM Detector

- ❑ Large area **CCD scanner** for GEM foils.
 - Original intent to monitor Tech-Etch foil quality (part of eRD3)
 - Now serving the broader MPGD community
 - eRD6 (Cr-GEMs, 10 cm x 10 cm)
 - eRD6 (Common EIC foil, 50 cm x 100 cm)
 - BONUS (15 cm x 20 cm)
 - Mecaro (Korean company working with CMS, 50 cm x 100 cm)
- ❑ Commercial large-area (~35 cm x 35 cm) triple GEM detectors.
 - Build and characterize **4 triple-GEM detectors** consisting of only **commercial parts**
 - Tech-Etch GEM, HV, and 2D readout foils
 - Based on the STAR FGT design
 - Unfortunately just as Tech-Etch established the manufacturing procedure, they stopped their GEM program.
 - Commercial prototypes were built with materials that Tech-Etch still had remaining around their facility.
 - These foils turned out to be rather poor quality.
- ❑ Use of **Kapton rings** rather than spacer grids.
 - Quantify the use of Kapton spacer rings in between the GEM layers rather than the more traditional spacer grids.



(a)

(b)

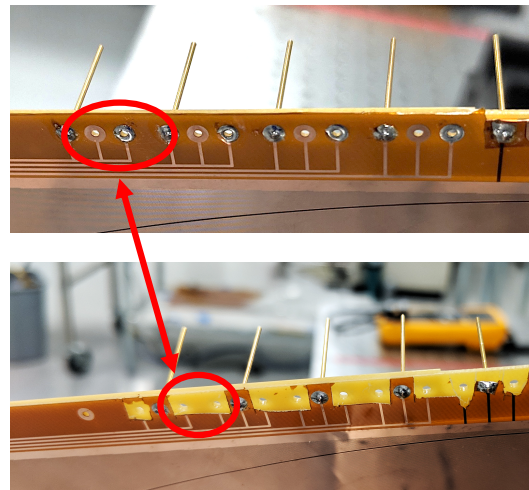
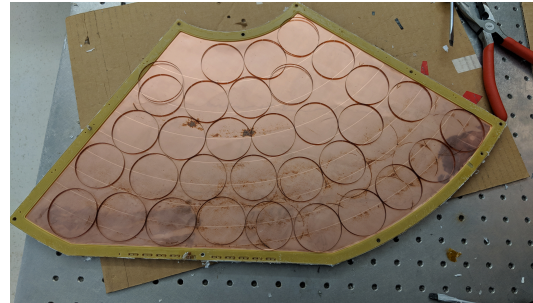


(c)

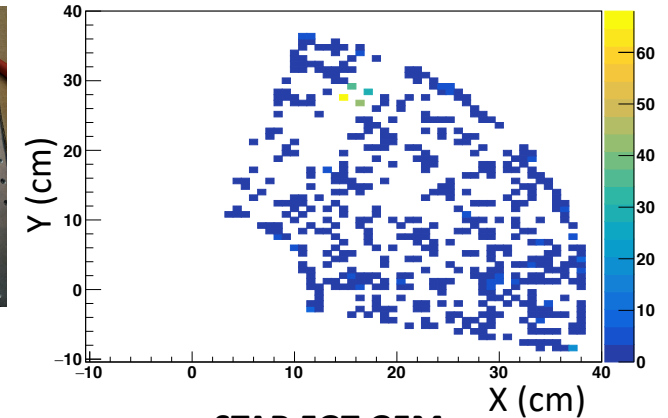
(d)

Commercial GEM Detector

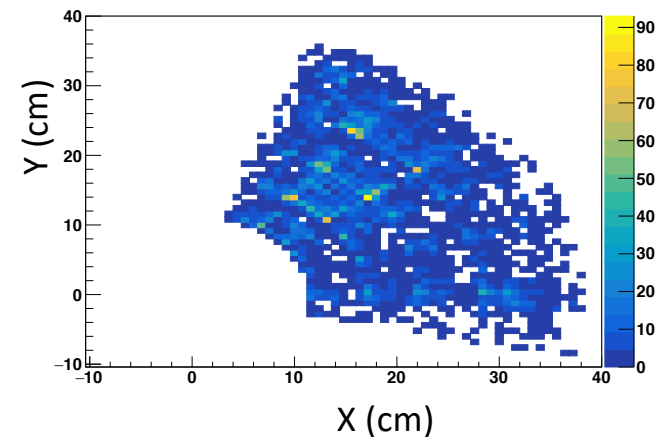
- ❑ The **first two** commercial GEM detectors experienced **excessive sparking** which killed the detectors.
 - **Unoccupied HV connectors** were found to be the cause.
 - The 3rd and 4th detectors had the **unoccupied HV connectors removed**.
- ❑ The **3rd detector** after assembly was found to have a **large leakage** current for **one of the three GEM layers**.
 - We were able to operate it effectively as a **double-GEM detector**.
 - From cosmic data
 - We noticed that **2 APV chips were dead** which resulted in some acceptance gaps.
 - Comparing to the reference STAR FGT detector we see the commercial detector is **less efficient**.
- ❑ The **4th** (and last) detector is showing **large leakage currents**.



Commercial GEM



STAR FGT GEM



Next Steps: Commercial GEMs and Kapton Rings

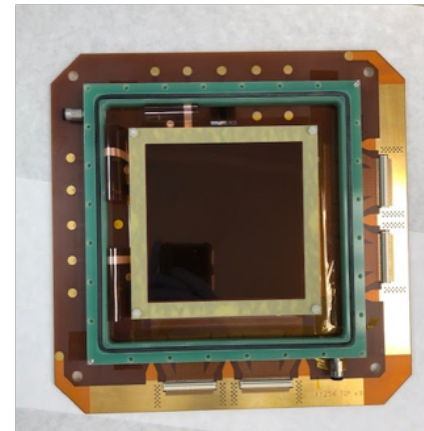
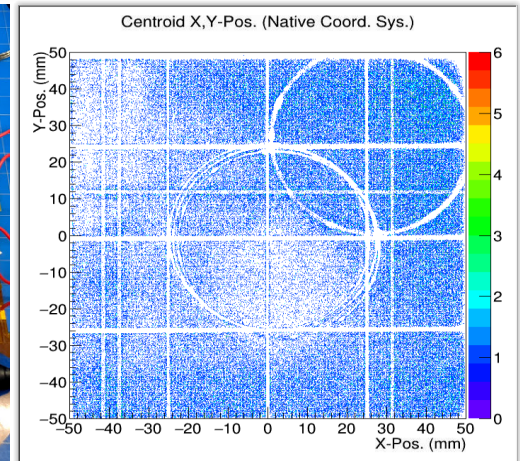
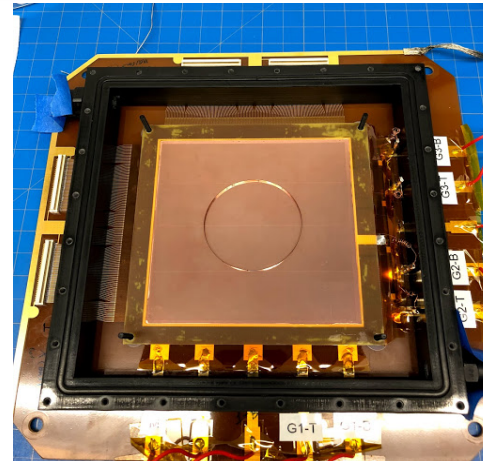
❑ FY20 R&D Plans for TU

○ Commercial triple-GEM Detector

- We are currently investigating the issues with the last two commercial GEM detectors.
- The detectors will most likely not be able to be fully characterized to our satisfaction.
- Since Tech-Etch has stopped GEM production, we are actively looking for other funding to purchase reliable commercial components to complete full characterization of low-mass triple-GEM detectors.

○ Kapton spacer rings

- TU received a phase 1 **SBIR funding** working with **Triton Systems** who will be investigating an **alternative technique** to produce 2D readout boards.
 - Proposal focuses on “**Direct Write Fabrication of Low Cost Flexible Particle Detector Substrates**”
- We are planning on using a **CERN 10 cm x 10 cm triple-GEM** detector and **SRS readout**, acquired from the SBIR, to repeat and build on initial measurements done by BNL.
- The effect of the **Kapton rings will be quantified** and compared to G10 space grids.
- SRS crate is expected at the end of the month.



Report on Particle ID

Report on Particle ID

Overview of Current PID R&D

❑ INFN

- Single-photon detection with MPGDs for high-momentum RICH
 - Resistive Thick GEM-MicroMegas hybrid prototype with miniaturized pad size.
 - NanoDiamond photocathodes for MPGDs.

❑ SBU

- Production of large mirrors for RICH detectors.
- Investigation of meta-materials for use in Cerenkov imaging detectors

Hybrid MPGD for RICH

❑ MOTIVATION

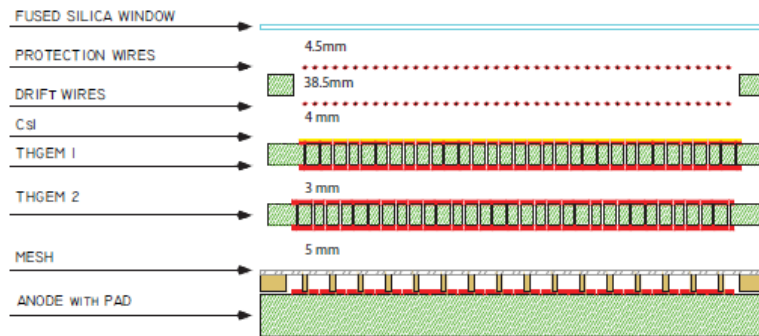
- A concrete option for PID at EIC for high momentum hadrons: **the window-less RICH** where the radiator gas is also the detector gas.

❑ REQUIREMENTS

- Reduce the radiator length
 - **Increase the number of detected photons.**
 - **Increase the space resolution** (shorter lever arm).

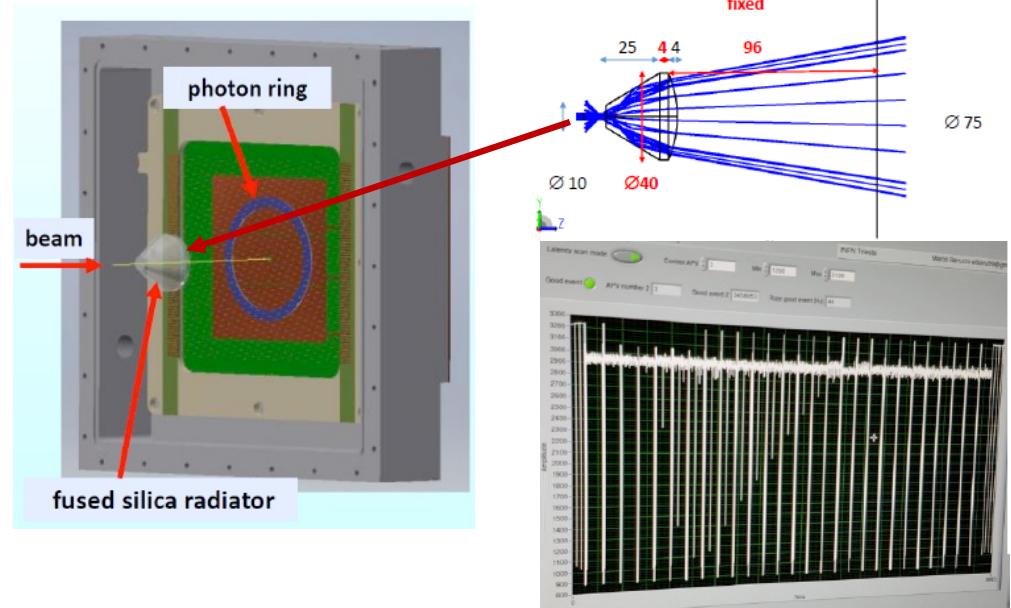
❑ THE STARTING POINT

- COMPASS RICH novel photon detectors



❑ Miniaturized pad-size prototype built and tested in beam

- Pad size $3 \times 3 \text{ mm}^2$
- Data collected with two gases: ArCH₄ (50:50) and pure Methane.

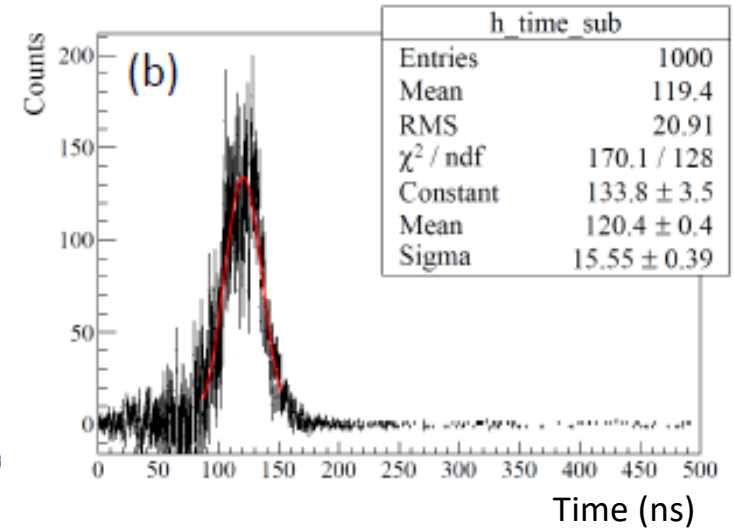
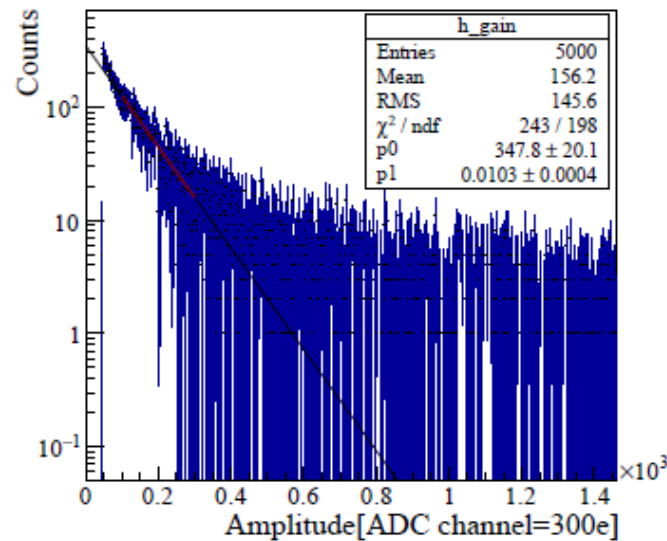
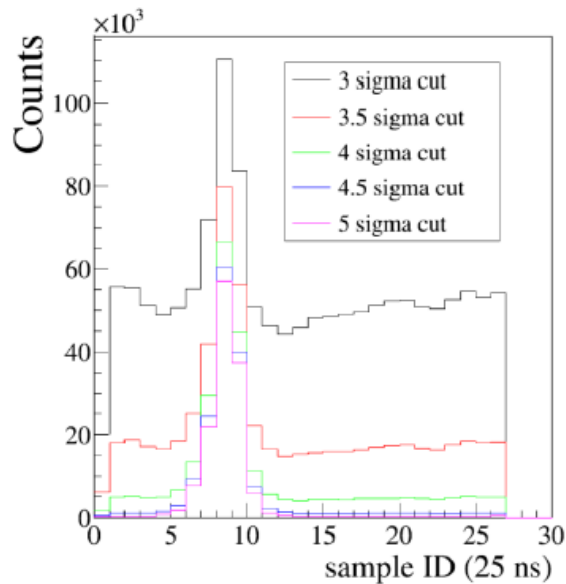
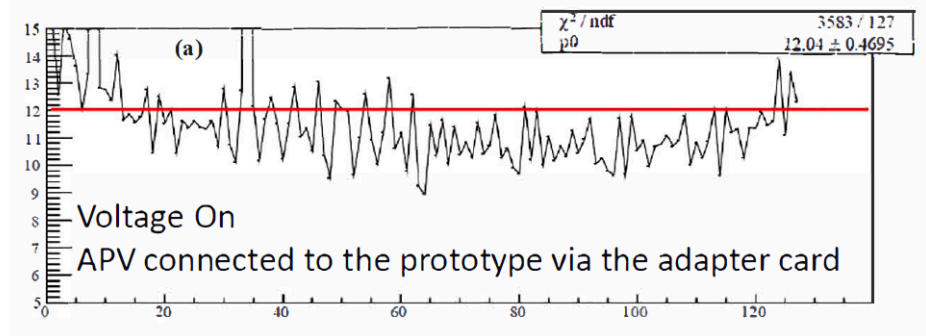


Signal as read by APV25 with SRS system and original DAQ
 "RAVEN": 27 frames, 1 every 25 ns

Hybrid MPGD for RICH

Miniaturized pad-size prototype: **ArCH₄ (50:50) Results**

- Noise level: ~ 3600 e⁻ (900 e⁻ at COMPASS!)
 - SRS not optimized for noise
 - Limits also from the compact geometry
- Timing and threshold studies carried out.
- Gain** from amplitude spectrum: **30k**
- Remarkable** timing resolution achieved: **14 ns**



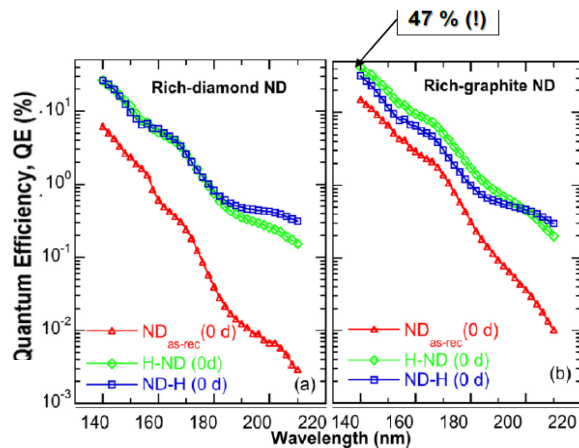
New Photocathode Materials development

MOTIVATION

- A more robust photocathode for gaseous detectors
- So far, the only usable one: CsI

QE of Hydrogenated (H)

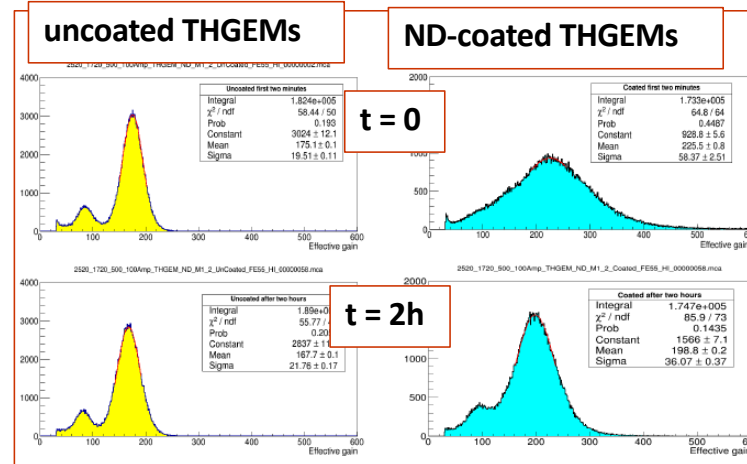
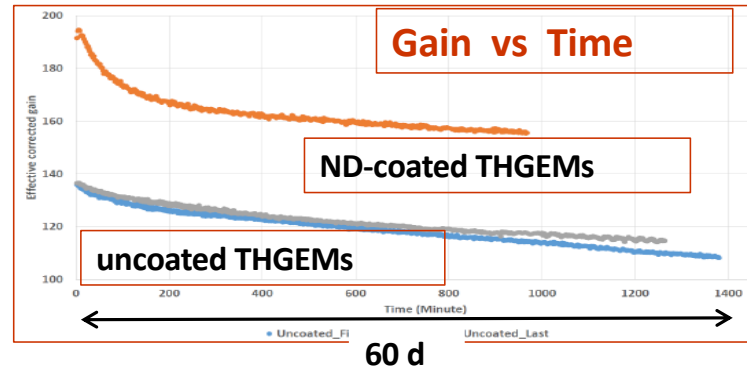
Nano Diamond (ND) powders



L. Velardi, A. Valentini, G. Cicala et al.,
Diamond & Related Materials 76 (2017) 1

- Extremely poor resolution with coating:
Being studied

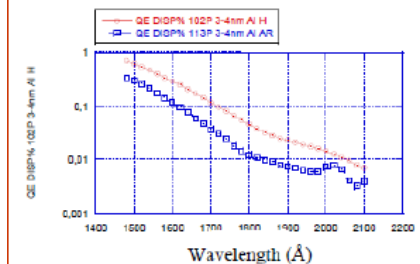
- Larger gain of coated THGEMs confirmed by long-term studies



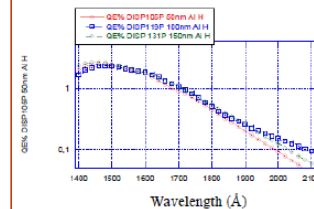
- Small grain size : low QE
- QE increases with grain size up to 50 nm.
- No QE improvement seen for grain size > 50 nm.

QE vs ND-grain-size

Grain-size: 3-4 nm



Grain-size: 50 nm (red)
100 nm (blue), 150 nm (green)



INFN Ongoing R&D Activities / 2019 Milestones

❑ Hybrid MPGD for RICH: Ongoing Activity

- Analysis of **pure methane** data from miniaturized pad-size prototype.
- Complementary lab exercises ongoing.
- The miniaturized pad approach reached a physical limit and can not further improve the space resolution
 - Obtain finer space resolution and better charge distribution by adding DCL resistive layer.
 - Design of the next prototype with DCL layer is already underway.

❑ 2019 MILESTONES

○ *September 2019:*

The completion of the laboratory characterization of the second version of the photon detector with miniaturized pad-size.

Status: delayed due to a change of goal; the new prototype will not simply be an optimized version of the present one, it will offer improved space resolution by resistivity and charge distribution

○ *September 2019:*

The completion of the studies to understand the performance of THGEMs with ND coating, both in the hydrogenized and non-hydrogenized versions.

Status: very advanced

Large Mirrors Development at SBU

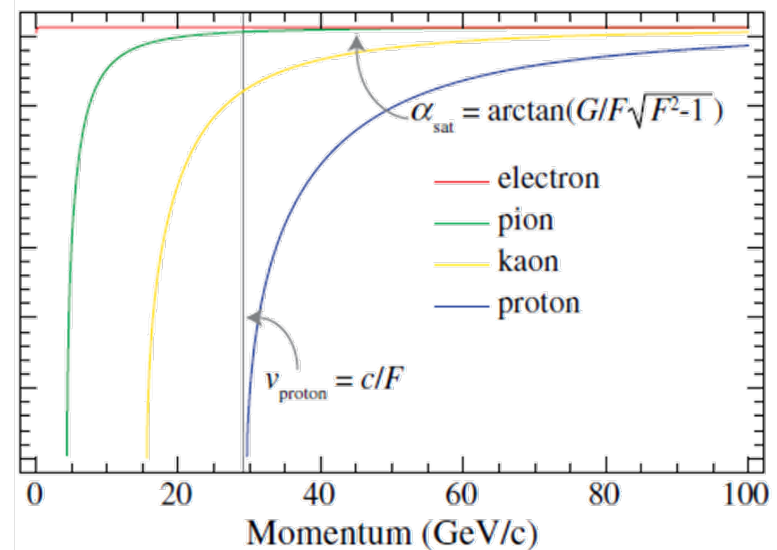
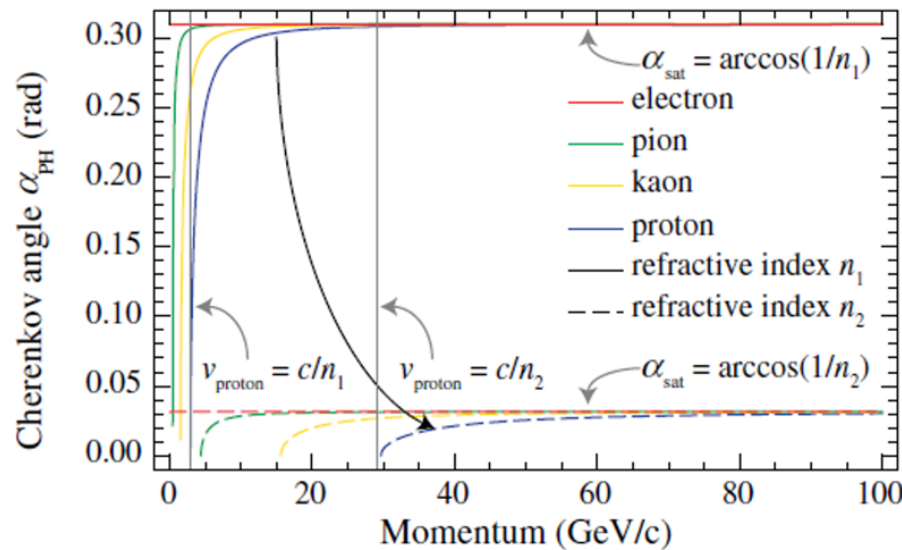
- ❑ Status of evaporator/mirror coating equipment
 - Evaporator moved to new location and being service installed
 - Devices for large mirror development
 - Electron beam device
 - Ion source device
 - Motorized rotator device
 - Devices installed in evaporator
 - Adjustments to be performed
 - MSc student assigned to assemble and commission the system

New Radiator Studies at SBU

- Aim: find radiator medium that combines properties of gas and aerogel.

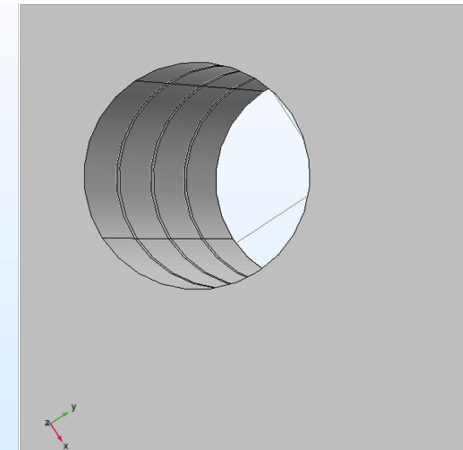
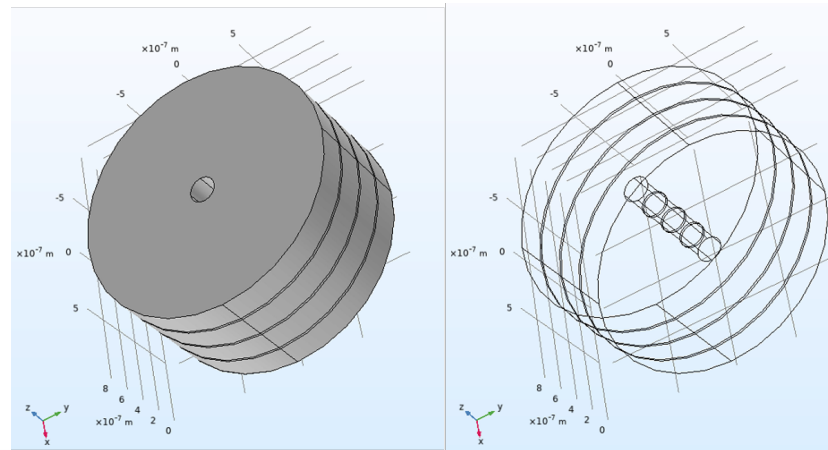
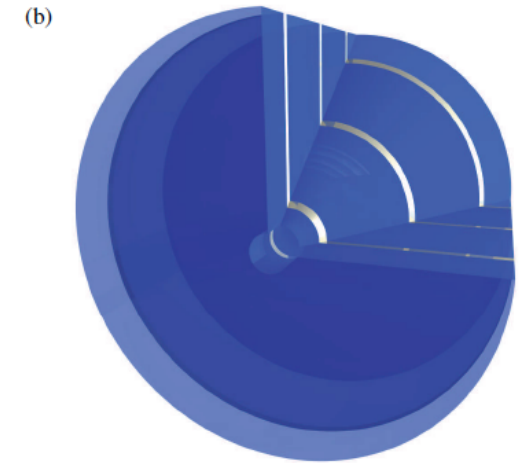
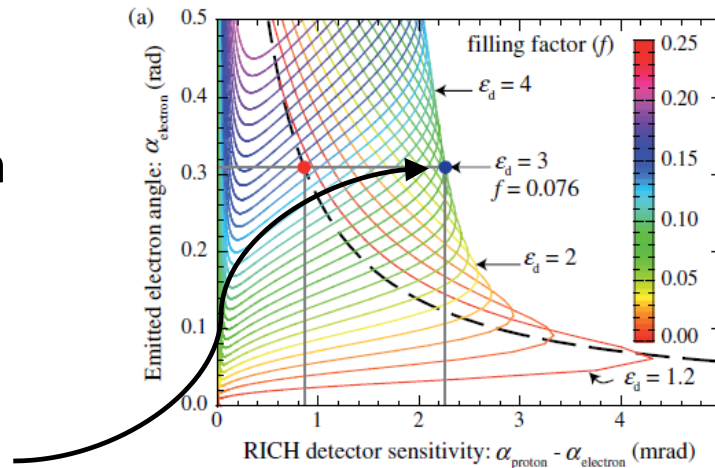
- Transformation optics yields $\tan(\alpha_{\text{PH}}) = \frac{k_y}{k_x} = \frac{G}{F} \frac{\sqrt{F^2 \epsilon_b \omega^2 / c^2 - k_x^2}}{k_x} = \frac{G}{F} \tan(\alpha^*)$

- “Stretch vacuum” such that $F = 1.0005$ and $G = 10$



New Radiator Studies at SBU

- ❑ Work started with COMSOL license
- ❑ UG students familiarizing with FEM software → learning curve
- ❑ Model created
 - Implementation of meta-material with parameters corresponding to
 - Slices of dielectric and silver with filling factor = 0.076
 - Dielectric thickness = 234 nm
 - Silver thickness = 20 nm



New FY20 R&D Proposal

New FY20 R&D Proposal

New Proposal: Outgassing Test Facility

❑ Motivation

- Test **new materials** (e.g. new 3D printed materials)
- Allows us to test for **cheaper alternatives** to currently used products (e.g. Nuvovern varnish)
- Provides **good synergy** within current eRD6 MPGD activities.
- Like the **GEM CCD** scanner at TU, the outgassing test facility would also serve the **broader MPGD community**, not just the EIC R&D community and build on the comments received from the committee

“Temple has established itself as a resource for the entire MPGD community and we recommend that the group actively maintain its support to the MPGD community”

❑ Outgassing system will be built to follow the established **ASTM E 595** procedure used by NASA and industry.

- Measures **Total Mass Loss (TML)** and **Collected Volatile Condensable Materials (CVCM)** from outgassing in a vacuum environment.

❑ Test procedure

- Test samples of **100-300 mg** are conditioned at **50% relative humidity for 24 hours** before testing.
- Sample is weighted and inserted into a vacuum at **5×10^{-5} Torr**.
- Sample is heated to **125°C** while collector plates, which are located above the sample are held at **25°C for 24 hrs**.
- Collector plates and sample are **cooled to room temp.** in desiccator and then weighed.

❑ **TML** is the difference between the sample weight before and after the test

❑ **CVCM** is the difference between the pre-test sample weight and the amount collected on the collector plates

❑ **Low outgassing** material meet **TML < 1%** and **CVCM < 0.1%**.

New Proposal: Outgassing Test Facility

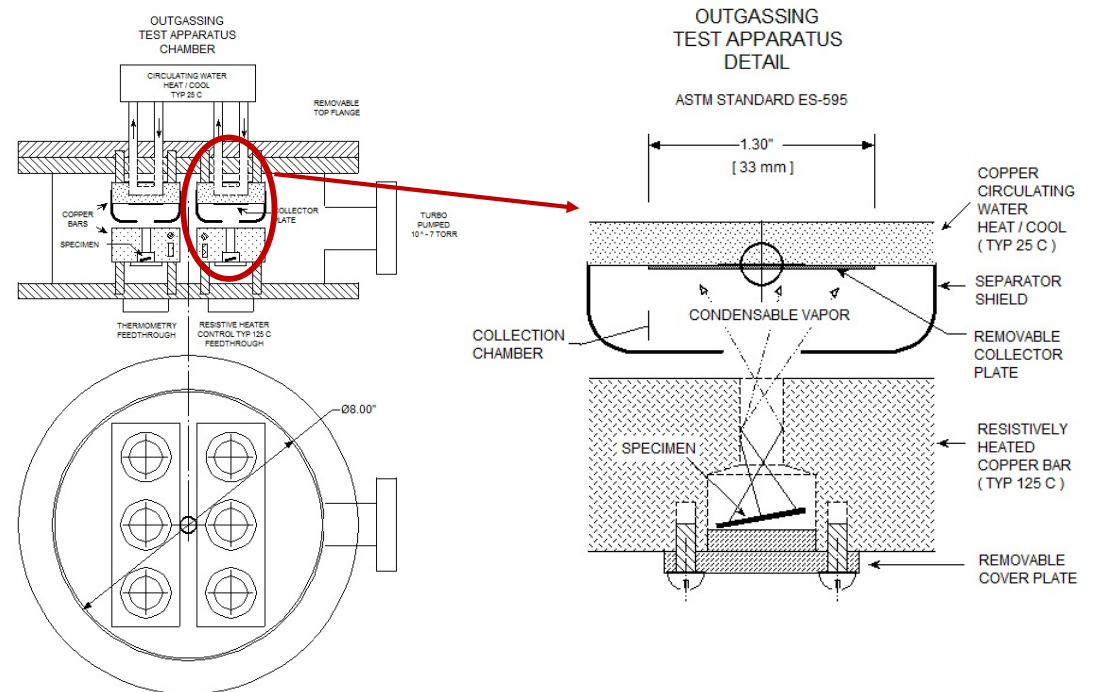
❑ TU Outgassing Apparatus

- The apparatus will be **designed** and **built** by **TU machine shop**.
- Majority of the cost comes from equipment (e.g. turbo pump system).
- Apparatus should allow for testing up to 6 samples simultaneously.

❑ To ensure setup is working properly

commissioning tests will be carried out on

- Empty samples – should see no outgassing effects.
- Reproduce results from NASA outgassing data base.
 - Select a few materials that have poor and good outgassing properties.



Initial TU rough draft design: **Not** finalized

FY20 Budget Overview Request

FY20 Budget Overview Requests

FY20 Budget Overview Requests: Central Tracking

□ Continuation of TPC R&D work

- BNL, Yale
 - Optimization and study of zigzag readout using different MPGDs for TPC.

□ Continuation of cylindrical μ RWELL activities

- FIT
 - Continuation of **design, production, and testing** of **mechanical mock-up** of cylindrical μ RWELL system.
- TU
 - Build a **planar 10 cm x 10 cm μ RWELL- μ TPC** with a **15 mm drift gap**, which matches current simulation drift gap, using a **standard 2D Compass readout**.
 - This detector will be used to **measure parameters** that will directly **feed into our simulation**.
 - Will be able to be used to further investigate the results found in last years standard μ RWELL built and tested by UVa.
 - Will be used as a **reference** for UVa's proposed low material readout μ RWELL operating in μ TPC mode.
 - Given the relative proximity of UVa and TU, **testing facilities** can be **shared**.
 - Study track-hit residuals of μ RWELL within EicRoot.
- UVa
 - Build a **low material 2D readout μ RWELL** operating in μ TPC mode.
 - Cosmic ray stand using two small triple-GEM detectors with 2D readout strips.
 - Acquire SRS-VMM readout.

FY20 Budget Overview Requests: Forward Tracking

□ Continuation of **forward GEM** tracking R&D activities

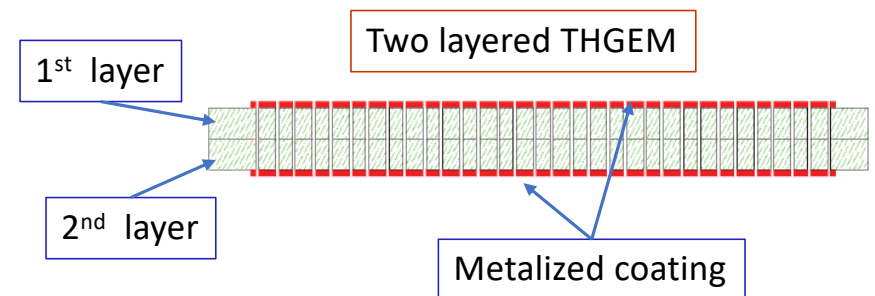
- FIT
 - Characterize performance of refurbished low-mass GEM prototype.
 - Study track-hit residuals of GEM trackers within EicRoot.
- UVa
 - Study impact of various Zebra connectors on large GEM prototype.
 - Test large prototype with SRS-VMM system.

FY20 Budget Overview Requests: PID

□ Continuation of ongoing **PID** R&D activities

○ INFN

- Construction and design of the second version (with DCL layer) of the photon detector with miniaturized pad-size.
- Assembly and characterization of THGEM formed with two layers.
 - Only one side of a layer will be coated with ND to avoid coating material inside the holes.



○ September 2020 Proposed Milestones

- The completion of the laboratory characterization of the second version of the photon detector with miniaturized pad-size.
- Study and characterization of a THGEM formed with two layers, coated with hydrogenated ND powder.

Nominal FY20 Money Matrix

☐ Fully loaded nominal FY20 funding request table.

\$k	MPGD RICH	Forward Tracker	μ RWELL Tracker	TPC Readout	Meta-Materials	Outgassing Test Stand	Total
BNL/YU	--	--	--	75.0	--	--	75.0
FIT	--	9.0	38.8	--	--	--	47.8
INFN	44.0	--	--	--	--	--	44.0
TU	--	--	15.8	--	--	56.2	72.0
UVA	--	13.0	20.1	--	--	--	33.1
Total	44.0	22.0	74.7	75.0	--	56.2	271.9

☐ In -20% and -40% scenarios each group reduces its request proportionally.

☐ Details on what aspect each group would reduce specifically are given in the backup slide tables.

The End

We would like to thank BNL and the Review Committee for all their support in making this a successful program!

Number of institutions/labs

7

Number of publications (list on next slides)

21

eRD6 Publications

❑ BNL

1. B. Azmoun et al. "*Design Studies for a TPC Readout Plane Using Zigzag Patterns with Multistage GEM Detectors*". In: IEEE Transactions on Nuclear Science (July 2018), pp. 1. [issn : 0018-9499](#). [doi : 10.1109/TNS.2018.2846403](#) .
2. B. Azmoun et al. "*Study of a Mini-Drift GEM Tracking Detector*". In: IEEE Transactions on Nuclear Science 63.3 (June 2016), pp. 1768. [issn : 0018-9499](#). [doi : 10.1109/TNS.2016.2550503](#) .
3. Craig Woody et al. "*Prototype Combination TPC Cherenkov Detector with GEM Readout for Tracking and Particle Identification and its Potential Use at an Electron Ion Collider*". In: 2015. [arXiv:1512.05309 \[physics.ins-det\]](#) .
[url : https://inspirehep.net/record/1409973/files/arXiv:1512.05309.pdf](https://inspirehep.net/record/1409973/files/arXiv:1512.05309.pdf) .
4. B. Azmoun et al. "*Initial studies of a short drift GEM tracking detector*". In: 2014 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC) . Nov. 2014, pp. 1. [doi : 10.1109/NSSMIC.2014.7431059](#) .
5. M. L. Purschke et al. "*Test beam study of a short drift GEM tracking detector*". In: 2013 IEEE Nuclear Science Symposium and Medical Imaging Conference (2013 NSS/MIC) . Oct. 2013, pp. 1. [doi : 10.1109/NSSMIC.2013.6829463](#) .

❑ INFN

1. J. Agarwala et al. "*The MPGD-based photon detectors for the upgrade of COMPASS RICH-1 and beyond*". In: Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2018). [issn : 0168-9002](#). [doi : https://doi.org/10.1016/j.nima.2018.10.092](#) . [url : http://www.sciencedirect.com/science/article/pii/S0168900218314062](http://www.sciencedirect.com/science/article/pii/S0168900218314062) .
2. J. Agarwala et al. "*Study of MicroPattern Gaseous detectors with novel nanodiamond based photocathodes for single photon detection in EIC RICH*". In: Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment (2019). [issn : 0168-9002](#). [doi : https://doi.org/10.1016/j.nima.2019.03.022](#) . [url : http://www.sciencedirect.com/science/article/pii/S0168900219303213](http://www.sciencedirect.com/science/article/pii/S0168900219303213) .

❑ SBU

1. M. Blatnik et al. "*Performance of a Quintuple-GEM Based RICH Detector Prototype*". In: IEEE Trans. Nucl. Sci. 62.6 (2015), pp. 3256. [doi :10.1109/TNS.2015.2487999](#) . [arXiv: 1501.03530\[physics.ins-det\]](#) .

eRD6 Publications

❑ FIT

1. Marcus Hohlmann et al. *"Low-mass GEM detector with radial zigzag readout strips for forward tracking at the EIC"*. In: 2017 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC 2017) Atlanta, Georgia, USA, October 21-28, 2017. 2017. [arXiv: 1711.05333 \[physics.ins-det\]](https://arxiv.org/abs/1711.05333). url: <http://inspirehep.net/record/1636290/files/arXiv:1711.05333.pdf>.
2. Aiwu Zhang et al. *"A GEM readout with radial zigzag strips and linear charge-sharing response"*. In: Nucl. Instrum. Meth. A887 (2018), pp. 184. [arXiv: 1708.07931 \[physics.ins-det\]](https://arxiv.org/abs/1708.07931).
3. Aiwu Zhang and Marcus Hohlmann. *"Accuracy of the geometric-mean method for determining spatial resolutions of tracking detectors in the presence of multiple Coulomb scattering"*. In: JINST 11.06 (2016), P06012. doi: [10.1088/1748-0221/11/06/P06012](https://doi.org/10.1088/1748-0221/11/06/P06012). [arXiv: 1604.06130 \[physics.data-an\]](https://arxiv.org/abs/1604.06130).
4. Aiwu Zhang et al. *"R&D on GEM detectors for forward tracking at a future Electron-Ion Collider"*. In: Proceedings, 2015 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC 2015): San Diego, California, United States. 2016, p. 7581965. doi: [10.1109/NSSMIC.2015.7581965](https://doi.org/10.1109/NSSMIC.2015.7581965). [arXiv: 1511.07913 \[physics.ins-det\]](https://arxiv.org/abs/1511.07913). url: <http://inspirehep.net/record/1406551/files/arXiv:1511.07913.pdf>.
5. Aiwu Zhang et al. *"Performance of a Large-area GEM Detector Read Out with Wide Radial Zigzag Strips"*. In: Nucl. Instrum. Meth. A811 (2016), pp. 30. doi: [10.1016/j.nima.2015.11.157](https://doi.org/10.1016/j.nima.2015.11.157). [arXiv:1508.07046 \[physics.ins-det\]](https://arxiv.org/abs/1508.07046).

❑ UVa

1. Kondo Gnanvo et al. *"Large Size GEM for Super Bigbite Spectrometer (SBS) Polarimeter for Hall A 12 GeV program at JLab"*. In: Nucl. Instrum. Meth. A782 (2015), pp. 77. doi : [10.1016/j.nima.2015.02.017](https://doi.org/10.1016/j.nima.2015.02.017) . [arXiv: 1409.5393 \[physics.ins-det\]](https://arxiv.org/abs/1409.5393) .
2. Kondo Gnanvo et al. *"Performance in test beam of a large-area and light-weight GEM detector with 2D stereo-angle (UV) strip readout"*. In: Nucl. Instrum. Meth. A808 (2016), pp. 83. doi : [10.1016/j.nima.2015.11.071](https://doi.org/10.1016/j.nima.2015.11.071) . [arXiv: 1509.03875 \[physics.ins-det\]](https://arxiv.org/abs/1509.03875) .

❑ Yale

1. S. Aiola et al. *"Combination of two Gas Electron Multipliers and a Micromegas as gain elements for a time projection chamber"*. In: Nucl. Instrum. Meth. A834 (2016), pp. 149. doi: [10.1016/j.nima.2016.08.007](https://doi.org/10.1016/j.nima.2016.08.007). [arXiv: 1603.08473 \[physics.ins-det\]](https://arxiv.org/abs/1603.08473).

eRD6 Publications

□ TU

1. M. Posik and B. Surrow. *"Construction of a Triple-GEM Detector Using Commercially Manufactured Large GEM Foils"*. In: 2018. [arXiv: 1806.01892 \[physics.ins-det\]](#).
2. M. Posik and B. Surrow. *"Construction of Triple-GEM Detectors Using Commercially Manufactured Large GEM Foils"*. In: Proceedings, 2016 IEEE Nuclear Science Symposium and Medical Imaging Conference: NSS/MIC 2016: Strasbourg, France. 2016, p. 8069743. [doi: 10.1109/NSSMIC.2016.8069743](#). [arXiv: 1612.03776 \[physics.ins-det\]](#).
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Backups

Backups

Funding Request: BNL and YU

	Baseline (k\$)	-20% (k\$)	-40% (k\$)
Single pattern zigzag readout boards	12	9.6	7.2
Additional GEM detectors	5	4	3
Micromegas for single pattern ZZ readout	5	4	3
μ RWELL for single pattern ZZ readout	5	4	3
Technical support	12	9.6	7.2
Gas and other expendables	6	4.8	3.6
Travel	5	4	3
Total	50	40	30
Overhead	25	20	15
Total with overhead	75	60	45

Funding Request: FIT

	Request	-20%	-40%
Graduate Student Stipends (2 stud.)	\$30,000	\$30,000	\$21,000
Undergraduate Summer Stipend	\$6,000	\$0	\$0
Travel	\$5,000	\$2,600	\$2,250
Materials	\$3,000	\$3,000	\$3,000
Indirect Cost Base (travel & material)	\$8,000	\$5,600	\$5,250
Indirect Cost (48% negotiated rate)	\$3,840	\$2,688	\$2,520
Total	\$47,840	\$38,288	\$28,770

Funding Request: INFN

❑ Personnel (globally equivalent to 3 FTE):

- From INFN Trieste:
 - C. Chatterjee (Trieste University and INFN, PhD student)
 - S. Dalla Torre (INFN, Sta)
 - S. Dasgupta (INFN, postdoc)
 - S. Levorato (INFN, sta)
 - F. Tassarotto (INFN, Sta)
 - Triloki (ICTP and INFN, fellowship)
 - Y. Zhao (INFN, postdoc)
 - *The contribution of technical personnel from INFN Trieste is also foreseen according to needs.*
- From INFN BARI:
 - Grazia Cicala (NCR sta and INFN)
 - Antonio Valentini (Bari University and INFN, professor)

❑ External Funding

- 2020 INFN support for this activity, requested: 25 k €
 - *Reminder* - 2019 INFN support : 22 k €

Table 6: Funding request INFN

item	cost	overhead	total
	(k\$)	(k\$)	(=cost+overhead) (k\$)
manpower	20	4	24
traveling	10	2	12
consumables	8		8
total	38	6	44

The resources already received in 2019 for the second version prototype will be used in 2020 (no double counting!).

Funding Request: TU

☐ Cylindrical μ RWELL μ TPC Request

Item	Request (\$)	-20% (\$)	-40% (\$)
Postdoc (%)	(10%) 5,637	(5%) 2,818	(5%) 2,818
Fringe benefits (26.85%)	1,513	757	757
Total Personnel	7,150	3,575	3,575
Material	800	800	200
Equipment	3,200	3,200	3,200
Modified Total Direct Costs	7,950	4,375	3,775
Overhead (58.5%)	4,651	2,559	2,208
Total Project Costs	15,801	10,134	9,183

☐ Outgassing Test Facility Request

Item	Request (\$)	-20% (\$)	-40% (\$)
Postdoc (%)	(20%) 11,274	(10%) 5,637	(5%) 2,818
Fringe benefits (26.85%)	3,026	1,513	757
Total Personnel	14,300	7,150	3,575
Material	10,000	10,000	10,000
Equipment	18,000	18,000	18,000
Modified Total Direct Costs	24,300	17,150	13,575
Overhead (58.5%)	14,216	10,033	7,941
Total Project Costs	56,216	45,183	39,516

Future Plans – Budget Requests

Future Plans & milestone for FY2020

❑ R&D on μ RWELL detectors:

- Continue the characterization of the 2D-strips μ RWELL prototype (Jan 2020)
- Build 2nd prototype with 2 cm drift and customized field cage to operate in μ TPC mode (Jan 2020)
- Take advantage of the timing capabilities of the VMM electronics for tracking studies (Jul 2020)

❑ Large GEM Prototype:

- Study the impact of various type of Zebra on position resolution of the prototype (Jan 2020)
- Test the prototype with VMM electronics and compare performances with APV25-SRS (Jul 2020)

❑ SRS-VMM Readout Electronics:

- Complete the acquisition of the small scale SRS-VMM system (Jan 2020)
- Familiarize with the system (DAQ & Software installation and configuration etc ...) (Jul 2020)

UVa Budget Request for FY2020

Item	Budget Request	-20% scenario	-40% scenario
μ RWELL- μ TPC	\$6,000	\$4,000	\$0.00
Two small GEMs	\$10,000	\$8,000	\$5,000
VMM Electronics	\$5,000	\$4,000	\$5,000
Zebras strips	\$1,000	\$1000	\$1000
Lab supplies & expendables	\$3,000	\$2,000	\$1,500
Travel (fully loaded)	\$5,000	\$4,000	\$3,000
Overhead (61%)	\$3,075	\$2,460	\$1,845
Total	\$33,075	\$25,460	\$17,345